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VIRG. GEORG. II. 20.

NEW-YORK:
G. & C. CARVILL & CO.
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ELEMENTS

OF

BOTANY

By ASA GRAY, M.D.

MEMBER OF THE CÆSAR. LEOPOLD. CAR. ACAD. NATURÆ CURIOSORUM, AND
OF THE LYCEUM OF NATURAL HISTORY, NEW-YORK.

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The medical enquirer is under great obligations to Botanical Science for affording a clue to the knowledge of the particular properties possessed by different plants; so that even if placed in a land with the vegetation of which he is wholly unacquainted, he may decide with confidence as to the species in which certain medicinal agents are or are not to be found; what plants are wholly inert, what kinds may be expected to produce esculent fruit, and what others should be looked upon with suspicion, or the mere contact with which

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Systematic writers commonly divide the Science of Botany into three departments, viz:

I. ORGANOGRAPHY, OR STRUCTURAL BOTANY; formerly styled *Vegetable Anatomy;* being the branch which comprehends a knowledge of the structure of Plants; including all that relates to the Elementary Tissues of which vegetables are universally composed, as well as the form and appearance of the various Organs produced by their combination.

II. VEGETABLE PHYSIOLOGY, OR PHYSIOLOGICAL BOTANY; which is devoted to the exposition of the vital actions or functions of the several organs of Plants, either separately or in combination.

III. Systematic Botany; which may be considered to include all that relates to the study of plants as individuals, enabling us to distinguish, describe, and arrange them. This department, which was formerly supposed to embrace the whole science, comprises three subordinate divisions, viz: 1. *Taxonomy*, or the Principles of Classification, being the application of our knowledge to the systematic arrangement of plants; 2. *Phytography*, or an exposition of the rules to be observed in describing and naming them; and 3. *Glossology*, which is devoted to the technical language used in the description of plants or their organs.

The study of the relations existing between vegetables and the Useful Arts, is sometimes viewed as constituting a fourth department of the Science, composed of several branches, such as *Agricultural Botany, Medical Botany, Economical Botany, &c.;* but these subjects are more justly considered as the connecting links between Botany and Agriculture, Medicine and other Useful Arts, than as distinct branches of our Science. The same may be said of what is termed *Geographical Botany*, which attempts the investigation of the circumstances regulating the distribution of vegetables over the earth's surface; a subject of great interest to the philosophical enquirer, but which, although intimately connected with Botany, is generally regarded as falling within the province of Physical Geography.

The arrangement here specified is for the most part adopted in the present work, except that it has generally been deemed advisable to treat of the functions performed by the several organs, while considering their modifications of form and structure. After having briefly noticed the simple or elementary tissues, which by their various combinations produce all the diversities of vegetable structure, we proceed to the consideration of the organs essential to the growth and complete developement of all Flowering plants, which on account of their office are generally termed the Organs of Nutrition or Vegetation. To this succeeds the highly interesting and important subject of Vegetable digestion and respiration, which leads us to notice the natural history of the elaborated juices, such as those which give rise to gum, sugar, starch, and other nourishing products, as well as the almost infinite variety of secretions and excretions. A wide field is here opened of interesting consideration and of great practical importance, which, however, in an elementary treatise like the present, can only be indicated in the most general manner. A cursory account of the special directions which the different organs assume, and the sensible movements they sometimes execute, closes this part of our subject.

In treating of the Flower and Fruit, it has been deemed advisable to consider them at the same time both with reference to their structure and physiology. We have also taken an early opportunity of directing the attention of the student to the views now entertained relative to the nature of the Floral Organs. The doctrine of Vegetable Metamorphosis, it should be remarked, was first suggested by Linnæus, but was so obscurely announced that it failed to attract the notice of any succeeding Botanist, until revived and admirably elucidated by the poet Gœthe. This subject, indeed, is to Botany what the Theory of the atomic constitution of bodies is to Chemistry; its principles, as triumphantly established by Du Petit-Thouars, Brown, and De Candolle, having given a new aspect to the Science, and rendered it, perhaps, the most logical of all the departments of Natural History.

Cryptogamous or Flowerless plants differ so essentially from all Vegetables of higher organization, that a chapter is devoted to their separate consideration, embodying all that the difficulty of the subject and the nature of an elementary work seemed to require. This concludes that part of our treatise which pertains to Structural and Physiological Botany.

We next enter upon the consideration of Taxonomy, or the Principles of Classification, a subject which cannot be pursued with any advantage whatever until the requisite knowledge of vegetable structure has been attained. We may here remark that while we would render all due acknowledgements to the Artificial System of Linnæus, which is certainly as well adapted as such a method can be to effect the object proposed by its author, we have nevertheless expressed our decided conviction, not only that it is no longer necessary, but that its adoption in any degree will, in fact, be found to retard the progress of the student. Indeed, whatever facilities it offers are greatly overbalanced by the uncertainty which attends its use, and the erroneous views with which it so generally impresses the young student. It is unnecessary, however, to insist upon this point, since, so far as our knowledge extends, the Natural System is now fully adopted by every Botanist of high and acknowledged reputation.

We have introduced a brief sketch of the principles of Botanical Nomenclature, chiefly with the view of early directing the attention of the student to this subject; since there is in this country a disposition to undervalue its importance, and needlessly to violate long established rules when nothing whatever is gained by the practice. No person should consider this subject as beneath his attention, and whoever introduces new names into the Science is certainly bound to frame them in accordance with the approved usage of Botanists.

Glossology, or the definition of the technical language employed in describing plants, closes our subject; and this we have greatly abridged by confining it absolutely to the definition of adjective terms; all substantive appellations, and even all adjective names restricted in their application to particular organs, being explained in the preceding part of the work.

We have added in an Appendix some general directions for collecting and preserving plants for the Herbarium, which we trust will be found useful to the young student. It is gratifying to observe the great improvement of modern practice in this particular, as is especially evinced by the fine and perfect specimens prepared by Mr. Oakes, Dr. Short, and several other Botanists. An imperfect and badly-dried specimen not only fails to exhibit the character of the species, but cannot be preserved for any length of time; whereas good specimens are, with moderate care, imperishable. From the want of proper attention in this respect, the collections of several of the older Botanists, made with great labor and expense, are now nearly valueless.

The Appendix also contains a list of the Natural Families, methodically arranged, which will, perhaps, be somewhat serviceable to those students who are not provided with the works of Lindley, De Candolle, Arnott, &c. A few remarks upon the relative importance of several Families in our Flora are also subjoined.

The want of proper works embodying the first principles of the Science, has been the chief obstacle to the advancement of Philosophical Botany in this country. The most valuable elementary works published in Europe are often too expensive ever to come into use in the United States; and even when these can be obtained, they are found deficient in that particular adaptation to our own plants which is so desirable to the American student. To apply in some degree the desideratum so long and deeply felt in this country by all who are interested in Botanical pursuits, the author was requested to superintend the republication of some one of the most approved European treatises. It was soon found, however, that of the works best adapted to our purpose some were much too large, others were illustrated with expensive engravings, or contained a considerable quantity of matter which did not seem to require a place in a mere elementary work. Upon the whole, therefore, it appeared that the desired object could not be thus accomplished without an unwarrantable mutilation of the treatise selected, and the introduction of a large body of notes. The author was accordingly constrained to alter his plan, and to engage in the more formidable task of preparing an original work, expressly adapted to the use of the student of North American Botany. The execution of this object is by no means easy, owing chiefly to the difficulty of combining rigid perspicuity and philosophical accuracy with a popular form and a familiar style. It is hoped, however, that the object in view will be found to have been in some degree accomplished.

In the execution of his task, the author has freely made use of all the most approved works and original memoirs upon the subject that were within his reach, and has more particularly and constantly consulted the

IV. Of the Floral Envelopes,
  1. Of the Calyx,
  2. Of the Corolla,
V. Of the Stamens, or Fertilizing System,
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VII. Of Fertilization, or the office of the Pollen,
VIII. Of the Fruit,
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CHAPTER V.

OF FLOWERLESS PLANTS,
1. Equisetaceæ, or Horse-tails,
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CHAPTER VI.

OF THE CLASSIFICATION OF PLANTS,
Sect. I. Of the Principles of Classification in general, Classes, Orders, Genera, Species, &c.
II. Of the Artificial System,
III. Of the Natural System,
IV. Of Nomenclature,

CHAPTER VII.

GLOSSOLOGY.

APPENDIX.

1. Directions for collecting and preparing Plants for the Herbarium,
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ERRATA,
INDEX,

ELEMENTS OF BOTANY.

CHAPTER I.

OF THE ELEMENTARY ORGANS OF PLANTS.

1. NOTWITHSTANDING the almost infinite diversity in the external forms of plants, their internal structure is remarkably simple and uniform. If, aided by a powerful microscope, we examine thin transverse slices of a stem or branch, we perceive a multitude of cavities, of various sizes, either angular or rounded. If we examine longitudinal slices of the same stem, we observe numerous cavities, closed by cross partitions, others without partitions, and bundles of slender threads, which run lengthwise through the plant. The closed cavities are called *cellules* or little cells, the tubes without partitions are *vessels*, and the slender threads are *fibres*. Of these minute parts, variously joined together, the stem, the root, the leaves, and all the organs of plants are constructed. They are, as it were, the material of the vegetable fabric, and are therefore very properly termed the Elementary Organs or Organic Elements of Plants. All the kinds of elementary tissue are nearly similar in chemical composition; they consist essentially of oxygen, hydrogen, and carbon, to which a little nitrogen is occasionally added. The three forms which the elementary organs assume are, 1st. *Cellular Tissue*, a structure made up of little cells only; 2d. *Woody Tissue* or fibre; and 3d. *Vascular Tissue* or vessels. These several forms we shall briefly notice in succession.

SECT. I. *Of Cellular Tissue.*

2. CELLULAR TISSUE, in its ordinary form, consists of masses of little vesicles or bladders, closed on all sides and cohering with each other. These little bladders are called *cellules.* A piece of honey-comb gives a very good idea of this kind of tissue; the walls of the cells represent the membrane, and the inclosed spaces the cavities, of the cellules. It may be most conveniently examined in the pith of plants, which wholly consists of cellular tissue. A thin slice of the pith of Elder, seen through a microscope, has much the appearance of fine honey-comb (*fig.* 1.), and the minute somewhat six-sided cavities thus brought into view are sections of the cellules. In most cases their walls adhere to each other so firmly that it is impossible to separate them, and the partition between contiguous cellules appears to be a simple membrane. Indeed Grew, who may be termed the discoverer of cellular tissue, considered it as a continuous mass pierced in every direction with innumerable holes. This view was adopted by many succeeding writers, and among others by Mirbel and De Candolle; but on further investigation both these distinguished botanists became satisfied of its incorrectness, and the theory has no advocate at the present day.

The cellules of pulpy fruits grow together so slightly that they may be detached from one another by simple maceration in water, and thus be examined in a separate state. In the pith of all plants, and in the parenchyma or green pulp of many leaves, we may bring about the same result by boiling the tissue a short time in a weak solution of potash. This proves in the most direct manner that the apparently simple membrane which separates adjoining cellules is composed of two membranes in a state of cohesion.

3. The size of the cellules varies much in different plants, and even in different parts of the same plant; in general they are largest in the most lax and rapidly-growing parts. The largest cellules are found

CONTENTS.

CHAPTER I.

Page.
OF THE ELEMENTARY ORGANS OF PLANTS, ... 1
Sect. I. Of Cellular Tissue, ... 2
II. Of Woody Tissue, ... 8
III. Of Vascular Tissue, ... 10

CHAPTER II.

OF THE ORGANS OF VEGETATION IN FLOWERING PLANTS, . 16
Sect. I. Of the Cuticle and its Appendages, ... 18
II. Of the Root, ... 26
III. Of the Stem
1. Of its External Modifications, ... 33
2. Of its Internal Structure, ... 40
3. Of the Growth of Stems, ... 53
IV. Of Leaf-Buds, ... 65
V. Of Leaves, ... 72
VI. Of Stipules and Tendrils, ... 100

CHAPTER III.

OF NUTRITION IN FLOWERING PLANTS, ... 103
Sect. I. Of the powers which plants possess for the performance of their Functions, ... 104
II. Of the Food of Plants ; and of absorption by the Roots, ... 108
III. Of the Ascension of the Sap, ... 113
IV. Of Digestion, and the Action of Leaves on the atmosphere, ... 115
V. Of the Descending or Elaborated Juice ; Secretions, &c., ... 121
VI. Of the Special Directions and sensible Movements of the Organs of Plants. 137

CHAPTER IV.

OF THE ORGANS OF REPRODUCTION IN FLOWERING PLANTS, 151
Sect. I. Of the Flower in general, Bracts, &c., ... 151
II. Of the Nature or Theoretical Structure of the Flower, ... 156
III. Of the Inflorescence, ... 169

IV. Of the Floral Envelopes, ...
1. Of the Calyx, ...
2. Of the Corolla, ...
V. Of the Stamens, or Fertilizing System, . .
VI. Of the Pistil, or Fructifying System, . .
VII. Of Fertilization, or the office of the Pollen, . .
VIII. Of the Fruit, ...
IX. Of the Seed, ...

CHAPTER V.

Of Flowerless Plants, ...
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III. Of the Natural System, ...
IV. Of Nomenclature, ...

CHAPTER VII.

Glossology. . . . .

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INDEX, ...

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3. The size of the cellules varies much in different plants, and even in different parts of the same plant; in general they are largest in the most lax and rapidly-growing parts. The largest cellules are found

in aquatic plants and in the Gourd tribe. In the gourd itself some of them are about the $\frac{1}{30}$ of an inch in diameter. Their usual magnitude is the $\frac{1}{400}$ or $\frac{1}{500}$ of an inch, but in many plants they do not exceed half this size. In some Mushrooms, of which the cellules are about the medium size, it has been calculated that "a sphere of the size of a large gourd will contain forty-seven thousand millions."

4. The primitive or normal form of the vesicles of cellular tissue is considered to be a sphere, as they always take a globular shape in loose and pulpy parts where they do not press on each other, as, for example, in the pulp of the strawberry and peach. When they are pressed together equally in all directions they become twelve-sided, and a cross section exhibits a hexagonal appearance (*fig.* 1.). The pith of all plants exists in this state, and extremely thin slices of the pith of Elder form an excellent illustration of it. On the other hand, if the pressure or the extending force be greater in one direction than in another, several other forms will be produced. Thus in parts which lengthen rapidly, as in leaf-stalks and the young shoots of herbaceous plants, the tissue is, as it were, drawn out, and the cellules assume the shape of prisms or cylinders.

Fig. 1.

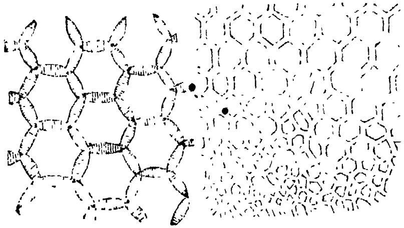
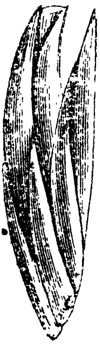
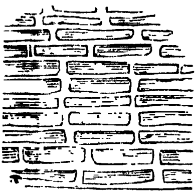


Fig. 2.



Sometimes these elongated cellules taper to a point at each end and become spindle-shaped (*fig.* 2.). This form abounds in the stems of trees and shrubs. It takes the place of rounded cellular tissue in the wood and bark, and the slender cellules lie in the same direction as the woody fibres (8).

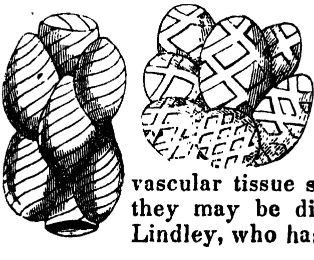
Fig. 3.



The medullary rays (36) are composed of cellular tissue, compressed laterally into thin plates; the cellules are elongated horizontally, and overlie each other, like bricks in a wall (*fig.* 3.), whence this form receives the name of *muriform* cellular tissue. It is peculiar, as we shall hereafter see, to the trees and shrubs of one of the great divisions or classes of Fowering plants (14). When the cellules fit together by plane faces, as in *figs.* 1 *and* 3, the tissue is sometimes called *parenchyma;* and Link proposes the term *prosenchyma* for those forms in which the cellules taper to each end, and overlap each other. The latter term, however, is seldom employed, and the former is frequently applied indiscriminately to all the kinds of cellular tissue, and especially to those which are pulpy or succulent.

5. Such are a few of the most commonly occurring forms of cellular tissue, in its ordinary state; that is, when it consists of membrane only. In some remarkable cases, however, this tissue is found to be composed either wholly of fibre, or of membrane and fibre combined, constituting those singular modifications which receive the names of *fibrous* and *fibro-membranous* cellular tissue. The fibro-membranous kind is common cellular tissue, with a spiral fibre generated in the inside of each cellule. It is found in the leaves of Peat-moss. (*Sphagnum*), and the pith of Rubus odoratus. In some cases there is a single spiral fibre; in others there are two, coiled in opposite directions, forming a kind of net-work (*Fig.* 4). These varieties seem to approach the nature of spiral vessels, (a form of vascular tissue soon to be described,) but they may be distinguished, according to Lindley, who has studied these tissues with

Fig. 4.



great acuteness, by their roundish shape, and by the coils of the spires being at a distance from each other, incapable of unrolling, inelastic, and possessing very little strength. This curious variety is also found in the skin of many winged seeds. Its particular use is unknown.

Fibrous cellular tissue is formed of fibres twisted spirally or otherwise, without any membrane. It exists in the lining of anthers (127), where it was first noticed by Mirbel, and quite recently it was again detected and very carefully studied by Dr. Purkinjé.* Professor Lindley discovered the same kind of tissue upon the surface of the seeds of Collomia linearis† of Nuttall, a native of the regions west of the Mississippi; recently introduced into gardens. The skin of the seed is furnished with an infinite number of minute threads, coiled up in spires, and confined by the hardened mucus which envelops the seed. If it be thrown into water, the mucilage is dissolved, and the threads dart forward into the fluid like so many spiral springs suddenly liberated by the removal of a weight which confined them. At first they were mistaken for spiral vessels, which indeed they very much resemble.

6. The vesicles of cellular tissue are destitute of visible pores; the appearance of holes and slits which Mirbel noticed, is known to have been an optical deception, caused by minute grains sticking to the sides of the cells.

The walls of the cellules are transparent and colorless, or nearly so; and the colors of leaves, flowers, &c., is owing entirely to the matters contained within. The principal coloring matter in all vegetables, is a substance consisting of very minute grains, which fills the cellules or adheres to their walls. It is colorless when excluded from the light, but when exposed to its action it becomes green, and gives to leaves and young stems their peculiar hue; and, undergoing certain chemical changes, it produces the various shades of red, yellow, and brown, which leaves present in autumn.

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* *De cellulis antherarum fibrosis*, &c. Breslau, 1830. See also Mirbel on the structure of the anther and pollen, in a paper annexed to his memoir upon Marchantia polymorpha, in which some fine figures illustrative of this tissue are given. For a more detailed account of these kinds of cellular tissue, see *Lindley's Introduction to Botany*, p. 10.

† Lindley, in *Botanical Register*, 1166, and *Introduction to the Natural System of Botany*, p. 217 of the American edition.

The colors of flowers are probably owing to other modifications of the same substance. In allusion to its obvious office in the vegetable economy, De Candolle distinguishes it by the name of *chromule*.[*] Dutrochet[†] advanced the idea that this substance is in plants analogous to the nervous system in animals; he accordingly gives it the name of *medulle*. Turpin[‡] calls it *globuline*, and supposes it the substance from which new cellules originate. Of the same nature is the green matter contained in the cellules of Marchantia polymorpha, or Brook-liverwort, recently described by Mirbel in his admirable memoir upon the structure and development of that plant. By the aid of very powerful glasses, these grains are seen to be little closed bags, which Mirbel calls *spherioles*, filled with a peculiar greenish matter.

Nearly all vegetable products or secretions (80, 82), such as starch, sugar, and milky juice, are found within the cellules.

7. In some cases cellules develop with very great rapidity. Many young stems increase in length at the rate of from one to three or four inches in a day. Some of the Mushroom family have been known to grow from a mere point to the size of a large gourd in a single night; in which case, if its cellules are of the medium size, they must have been produced at the rate of about 4,000,000,000 per hour.[§]

That cellules have the power of producing other cellules, has been conjectured by several vegetable physiologists, but quite recently Mirbel has clearly proved this to be the case, and has ascertained the way in which the cellules of Marchantia are formed, in a manner that leaves little to be learned respecting that plant. His observations are contained in two highly interesting papers, communicated to the French Academy of Sciences, in the years 1831 and 1833.*

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[*] From χρωμος, *color.*

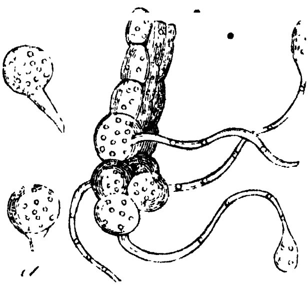
[†] *Mem. du Museum*, 7. p. 389.

[‡] *Mem. du Museum*, 18. p. 212.

[§] *Lindley, Introduction to Botany*, p. 7.

The seeds, or, as they are more properly called, *spores* of Marchantia, are minute and simple vesicles, filled with yellow globules. When they are placed upon moistened plates of glass, or in fine sand in a warm and damp atmosphere, they increase in four days to about three times their original size, and the yellow matter within them becomes greenish. About this time a projecting point appears upon each vesicle (*fig.* 5. *a.*), which soon elongates into a slender tube. This tube swells out at its extremity, and becomes a second cellule similar to the original one. The newly-formed cellule emits a similar tube, which grows into a new cellule with its tube, &c. The young plant at first appears like a knotted cord; next it becomes a shapeless mass of green matter, and finally the cellules arrange themselves symmetrically, the mass by degrees becoming leaf-like, and assuming the appearance of the full-grown plant. *Fig.* 5. from Mirbel, is intended to represent the earlier stages of this growth by the production of new cellules. It is probable that all vegetables composed wholly of cellular tissue, grow in a similar manner.

Fig. 5.



Cellular tissue abounds in all plants. The Sea-weeds, the Lichens, Mushrooms, Mosses, &c., are entirely formed of it, and are therefore called CELLULAR PLANTS. Pith is wholly composed of this tissue; it is found in the root, the bark, and the leaves of all vegetables; and it is abundant in all fruits, especially in those that are pulp-like. It is the earliest-formed tissue in growing parts, and it makes up by far the greatest portion of all young plants.

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* *Recherches anatomiques et physiologiques sur le* Marchantia polymorpha, *pour servir a l'histoire du Tissu cellulaire.*

Cellular tissue absorbs fluids very readily, which flow from one cellule to another; consequently their walls are permeable to fluid, although they have no visible pores. The sap and other juices of the plant are circulated principally by means of cellular tissue; but this subject will be noticed in another place.

SECT. II. *Of Woody Tissue.*

8. WOODY TISSUE consists of very slender, tough, and transparent tubes, which taper to a sharp point at each end. These little tubes lie in bundles, or are, as it were, spliced together so as to form long fibres, which run lengthwise through the plant. The fibres of hemp and flax, which are made into cordage or cloth, are very good examples of woody tissue. If we examine the finest filament of flax with the aid of a powerful microscope, we shall perceive that it is not a simple fibre, but is made up of numerous fibres of different lengths, very closely joined together and overlapping each other by their extremely slender extremities. By continued maceration in water, or, which is much better, in water containing a little nitric acid, their cohesion is destroyed, so that by delicate manipulation, the simple fibres may be obtained in a separate state. In hemp their diameter is about six times smaller than a human hair; but in many woody plants they are somewhat larger. It is very difficult to ascertain by direct observation that these minute fibres are hollow, yet it is thought to be proved, not only by examination with a high magnifying power, but by the occasional detection of particles of greenish matter within the tube. Woody tissue is considered by several vegetable anatomists as a modification of cellular tissue. It differs,

however, from any known form of elongated cellular tissue by the more slender, stronger, and much more elastic fibres. Elongated cellular tissue is composed of blunt cylinders placed end to end: the fibres of woody tissue are sharp at each end, and overlap each other. This difference will be appreciated at once by comparing, under a high magnifying power, the fibre of cotton, which is cellular tissue, with that of hemp or flax. Woody fibre makes up a large portion of the bulk of shrubs and trees; but it also exists in the stems of herbs, giving them toughness and strength. It likewise abounds in the bark, and in the frame-work of the leaves.

The office of this tissue is not only to give strength to the vegetable fabric, for which purpose its structure is admirably adapted, but also to assist in the conveyance of the sap from the root to the leaves. Whether fluids pass through the hollow fibres, or between them, it is impossible to ascertain by direct proof.

The uses of woody fibre in the arts, as in the manufacture of linen, paper, cordage, &c., are familiar to every one.*

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* The wood of the Pine, and of all the Coniferæ or Fir tribe, presents a remarkable peculiarity which has of late attracted considerable notice. The fibres, which are much larger than those of most woody plants of other families, are conspicuously marked with numerous dots of an uniform size and appearance. They have been described as pores, but they seem rather to be globules, (sometimes transparent and sometimes partially or entirely filled with opaque matter,) situated within the substance of the walls of the tube. Whatever may be the nature of these dots, they are only seen in Coniferæ and in Cycadæ, a nearly related family which is confined to tropical regions, thus furnishing us with the means of distinguishing the wood of these plants from all other. By taking advantage of this circumstance, Messrs. Witham and Nicol have made the interesting discovery that all Exogenous fossil woods (so far as is at present known) belong either to the Fir tribe or to Cycadæ; from which it follows, that these families formed a much more conspicuous feature of the original, than of the present, vegetation of the globe. This adds another to the many instances in which the careful study of minute structure has led to the discovery of important truths. The manner in which these gentlemen operated upon fossil woods is very simple. Sections of the stem to be examined are attached to plates of glass by a transparent cement

Sect. III. *Of Vascular Tissue.*

Fig. 6.

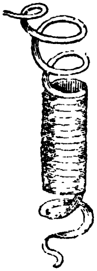


Fig. 7.

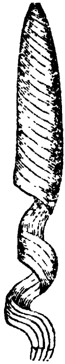
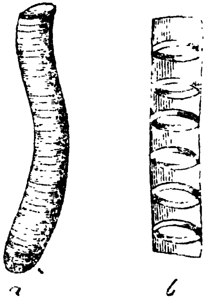


Fig. 8.



9. The vascular tissue of plants consists of slender, unbranched, cylindrical tubes, whose calibre is not interrupted by transverse partitions. The vegetables which have this tissue in their composition, are called VASCULAR PLANTS. There are two principal kinds of vascular tissue, viz.: *spiral vessels* and *ducts*.

10. SPIRAL VESSELS (*fig.* 6. 7.), or *tracheæ*, as they were originally called, may be assumed as the representatives of vascular tissue in plants. They were discovered by Henshaw, in the year 1661. If we carefully break young stems of the Rose, Gooseberry, or Currant, or tear off the leaflets of the Strawberry, we shall bring these vessels into view in great numbers. To the naked eye they appear like fine sil-

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and ground down to the thinnest possible plates, when they transmit light so readily that their structure may be ascertained by the microscope in the ordinary way. It is very desirable that the substance called *mineral charcoal*, which is occasionally met with in our anthracite mines, should be submitted to this examination. Mr. Witham published the results of his investigations in a separate work, illustrated with many fine plates.

very threads, not larger than those of a spider's web. They seem to possess great elasticity, as they are capable of being extended very considerably without breaking, and, when the extending force is withdrawn, they return nearly to their former dimensions. If we examine them by the aid of a microscope, we observe that the threads are coiled spirally, like a wire spring; in their natural situation, the coils are in contact, so as to form a tube, but they unroll elastically whenever they are extricated from the adjoining tissue.

The nature of these vessels has been, for a long time, a contested point in vegetable anatomy. The delicate fibre which forms the spires, has, by some observers, been thought to be flat, or thickened at the edges; others have described it as grooved on the inside. The most recent observations, viz., those of Professor Lindley, render it almost certain that the fibre is round; but whether it be tubular, as is represented by Mirbel, or solid, as many believe, has not been determined; and Amici, who has examined it with the most powerful glasses, declares that the question cannot be decided by the means in our possession. Many vegetable anatomists consider spiral vessels to consist exclusively of elastic fibre twisted into the form of a cylinder, and this appears to be the opinion of Mirbel and De Candolle. Dutrochet thinks that the edges of the coils are united by a delicate and transparent membrane, which is torn whenever the vessel unrolls. Others have supposed that the thread is coiled on the outside of a straight, membranous cylinder; and, finally, Bernhardi contends that the fibre is coiled within a membranous tube, which, by its elasticity, it serves to keep open. The last-mentioned view is the one adopted by Lindley,* and is best sustained, both by observation and analogy, although the existence of the membrane outside the spires can seldom be directly proved.

Spiral vessels are most frequently formed by the coiling of a single fibre, as in *fig.* 6, when they are said to be *simple;* but in many plants of the Endogenous structure (33) they are *compound*, or made by the union of several fibres, as in *fig.* 7.

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* *Introduction to Botany*, p. 18.

Their diameter varies from the $\frac{1}{300}$ to less than the $\frac{1}{1000}$ of an inch. In plants of Exogenous growth (33) they are placed immediately around the pith of the stem and branches, whence they extend into the leaves and all parts that are modifications of leaves. The veins, or fibrous net-work of leaves, consist of spiral vessels, protected on every side by woody fibre.

The spiral vessels do not occupy the central part of the trunk in Endogenous plants, but are placed in the midst of each bundle of woody fibres, and from these bundles they pass into the veins of the leaves. They are altogether wanting in Flowerless plants (14), except in Ferns, and the Club-moss tribe; two families which occupy a middle space between Flowering and Flowerless plants.

Spiral vessels do not convey fluid, as was once supposed, but are filled with air in the living plant, and seem to be intended for its conveyance through the central parts of plants. They appear to be connected in some unexplained way with the production of flowers, for plants which have no spiral vessels never bear flowers.

11. Ducts (*figs.* 8, 9, 10.) are membranous tubes, whose sides are marked, often in an evident spiral manner, with rings or transverse lines. They are thought to be mere modifications of the spiral vessel, from which they are to be distinguished chiefly by their want of elasticity and the power of unrolling. They abound, however, in situations where true spiral vessels are never seen, and are probably subservient to different purposes.

The various kinds of ducts may be reduced to three principal forms, viz.: the annular, the reticulated, and the dotted.

Annular ducts (*fig.* 8.) are membranous tubes, kept open by a series of fibrous rings; or we may view them as spiral vessels with the thread broken at every coil into separate rings. Sometimes the rings are placed at a considerable distance from each other, and again they are in contact, in which case the external appearance of the duct is the same as that of a spiral vessel. Both these varieties abound in the roots of most herbaceous plants, and in the stems of Ferns.

Fig. 9.

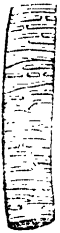
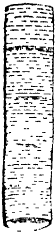


Fig. 10.



In *reticulated* ducts (*fig.* 9.) the rings are broken into several pieces, which sometimes grow together irregularly, and form a kind of net-work upon the walls of the vessel. The membranous and transparent spaces between the bands have been mistaken for holes and slits in the tube. Vessels of this kind are quite common in the stems both of herbaceous and woody plants.

Dotted ducts (*fig.* 10.) are so called from having their walls marked with rows of dots, which appear to be adhering grains of green matter. They are larger than any other kind of vessels, and when young they have transverse partitions, at which they readily separate. They are, therefore, very properly considered to be a modification of cellular tissue, and to be made up of a series of short cylindrical cells, placed end to end, so as to form slender columns extending the whole length of many stems. The lines on the outside, produced by the junction of the cellules, give the column something of the appearance of the spiral vessel; and on this account it has been referred to vascular tissue. Dotted ducts are found in the wood exclusively; their open mouths are very evident to the naked eye in transverse slices of the Oak or Vine, giving them a porous appearance.

The peculiar office of ducts is not very well understood. In young stems, and at particular seasons, they are filled with fluid; at other times they seem to contain nothing but air.

12. Several vegetable anatomists maintain that ves-

sels and woody fibre are not simple elementary tissue, but only modifications of cellular structure. Mirbel* advanced this view many years ago, and has lately sustained it, and adduced many curious facts in its favor, in his memoir upon the structure of Marchantia polymorpha. In this plant, which is well known to consist wholly of cellular tissue, he has seen roundish cellules change into long and slender tubes, and has observed the transformation of these tubes into what he supposes to be true spiral vessels. These extraordinary modifications will perhaps be considered as forms of fibrous cellular tissue (5), but whatever view may finally be adopted respecting them, it will always be necessary practically to distinguish the three kinds of tissue here described. Those who are desirous of examining this subject more fully, should consult the interesting memoir of Mirbel, to which we have several times had occasion to refer.

13. The rounded cellules and cylindrical tubes of which the vegetable structure consists, cannot be applied to each other in masses so as to fit exactly; little spaces being necessarily left between their sides. called *intercellular passages.* They are usually triangular, but their form depends upon the number of cellules which enter into their composition. They are always filled with fluid in the living plant, and are supposed to assist in its transmission from one place to another.

It sometimes happens that the peculiar secretions or products of a plant are deposited in the intercellular passages, and pressing upon the neighboring cellules, they form cavities of very considerable size, which are termed *receptacles of proper juice.* Of this nature are the turpentine-cells in the bark of the Pine and Fir.

The transparent dots in the leaves of the Orange and Myrtle are caused by the presence of little globular receptacles of this kind, which are sometimes called

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* *Traité d'Anatomie et de Physiologie Végétales,* 1802; and *Elémens de Physiologie Végétale et de Botanique,* 1815.

vesicular glands. *Fig.* 11. (from Lindley) is a magnified view of one of these glands, or rather receptacles of aromatic oil, in the rind of a lemon. They are several times larger than those observed in the leaves.

Similar receptacles exist in the form of oblong bags in the fruit of Umbelliferous plants. It is upon the oily matter which these receptacles contain, that the peculiar flavor of caraway and coriander seeds depends.

Fig. 11.

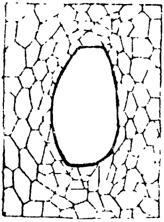
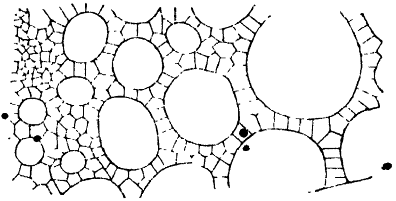


Fig. 12.



In many plants there are cavities built up of cellular tissue in a similar manner, but which never contain fluid. Such are *air-cells.* They abound in the stems of water-plants, in which they are constructed with a wonderful degree of uniformity in each species. Sections of the stems or leaf-stalks of the Pond-weeds and the Arums, exhibit them very beautifully (*fig.* 12.). They are obviously destined to render the plant buoyant in water. The hollow stems of grasses, rushes, and Umbelliferous plants are caused by the rapid growth of the stem itself, which increases faster than the tissue of the pith can be produced; and the latter is consequently distended, and torn into irregular cavities.

CHAPTER II.

OF THE ORGANS OF VEGETATION IN FLOWERING PLANTS.

14. THE three kinds of tissue described in the preceding chapter, viz.: the cellular, the woody, and the vascular, are the only elements which enter into the composition of plants. These simple tissues, variously combined, make up the whole vegetable body, with all its varieties of external form and internal structure. But they are not all essential to the existence of every form of vegetation. We have already had occasion to remark that the *lower orders* of plants are composed of cellular tissue alone; this tissue, consequently, is the only element which is absolutely essential to vegetable life. The woody and vascular tissues are, however, quite as indispensable in the more complex organization of perfect plants: since, destitute of woody fibre, they cannot grow to any considerable height; and without vascular tissue, are incapable of producing flowers or seeds.

If we contemplate vegetables as a whole, looking at their elementary structure only, we obtain a division into two grand classes:

1st. Plants into whose organization the three kinds of elementary tissue enter, and which, being especially characterized by the presence of spiral vessels, are called VASCULAR PLANTS.

2d. Those which are essentially composed of cellular tissue only, receive the name of CELLULAR PLANTS.

But it has also been observed, that the presence of the most perfect form of vascular tissue, that is, of spiral vessels, is, in some way, intimately connected with the production of flowers; so that plants in which these exist, may be expected to bear flowers and seeds, which are in no instance produced in their true form by Cellular plants. These two grand divisions may thus be equally distinguished by the presence or absence of flowers and seeds, and their leading characters may be defined as follows:

Class I.—VASCULAR, OR FLOWERING PLANTS.

Plants furnished with spiral vessels, capable of bearing flowers, and reproduced by seeds.

Class II.—CELLULAR, OR FLOWERLESS PLANTS.

Plants destitute of spiral vessels, and incapable of producing true flowers or seeds.

It is important that this primary division be kept in view, and frequent reference will be made to it as we proceed.*

The elementary organs, by their combination, produce the root, stem, leaves, flowers, fruit, &c., or, as they are collectively termed, the *External* or *Compound Organs* of plants.

These organs are generally distinct from one another in Flowering plants, and each performs its separate office: they are, moreover, formed upon the same general plan in all of them. In Flowerless plants, on the contrary, the root, stem, and leaves are frequently more or less confounded with one another, and each family seems to be formed upon a plan peculiar to itself; so that it becomes necessary to treat of the structure of these plants in a separate chapter.

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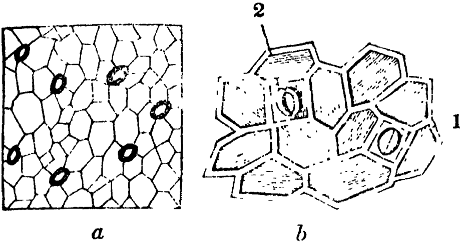
* In strict accuracy it should here be mentioned, that there are two groups intermediate between Vascular or Flowering, and Cellular or Flowerless plants, viz.: the Ferns, and the Lycopodiaceæ or Club-moss tribe, which have nearly the same structure as some Flowering plants; that is, they abound in annular ducts, and some of them have a few spiral vessels, yet they never bear flowers or seeds. Thus these plants connect the two classes with each other.

There are two kinds of compound organs in Flowering plants. Some are essential to the life and growth of the vegetable; these are called the *Organs of Vegetation* or *Nutrition.* Of another sort are those which do not contribute directly to the growth of the vegetable, but are subservient to the continuance of the species; these are termed *Reproductive Organs.* To the first division belong the root, the stem, and the leaves; to the second, the flower and fruit. In the present chapter we are to consider solely the organs of vegetation.

Inasmuch as these organs are essential to the complete development of the individual, and consequently exist in some form in all Vascular plants, and, as will hereafter appear, the reproductive organs being merely modifications of the stem and leaves, the former are very properly called by De Candolle the *Fundamental organs* of plants.

SECT. I. *Of the Cuticle and its Appendages.*

Fig. 13.



15. The whole surface of a plant, except the stigma (136) and the growing extremities of the roots, is covered with a thin and transparent membrane, which, from its resemblance to the scarf-skin of animals, is called the *cuticle.* To the unassisted eye it appears to be a simple film, but with the aid of powerful glasses it is seen to be traversed by fine lines, which are usually interlaced so as to form a delicate net-work (*fig.* 13, *a.*). The meshes are, perhaps, most commonly six-sided, as in *fig.* 13, *b*, which is a highly magnified view of a piece of cuticle; they are often four-sided, and not unfre-

quently their outline is so irregular that they can be referred to no symmetrical form.

There are two opinions concerning the nature of the cuticle. Some authors, among whom are Keiser, Amici, and Brongniart, consider it a peculiar membrane, quite distinct from any other kind of vegetable tissue; others are inclined to consider it as an external layer of cellular tissue, hardened by the prolonged action of light and air; and of this opinion are Mirbel, Link, and Lindley. The meshes of the cuticle are thought, by those who sustain the former opinion, to be a network of veins or nourishing vessels; but by the others they are inferred to be the united sides of the vesicles of which the membrane is composed. It is unnecessary for our present purpose to state the arguments by which these opposing views are sustained; the more so, as the structure of the cuticle is now pretty well understood, whatever difference of opinion may exist respecting its origin. That it is not a simple membrane may be proved in the most satisfactory manner, by the examination of thin transverse slices under the most powerful glasses. It is found to be made up of a vast number of little vesicles, so arranged as to form one or several layers. In most plants of this climate, the cuticle consists of a single layer of cellules; but in succulent and other plants growing naturally in arid situations, it is found with two, three, and sometimes a greater number of layers.

Although it is quite certain that the cuticle is a form of cellular tissue, yet it by no means follows that it is merely the external layer of the cellular tissue of the bark. This seems to be the case in certain Flowerless plants only, but in plants of a higher organization, the cells of the cuticle are often of a very different form from those of the tissue beneath. In Flowering plants, at least, the cuticle must be considered, not as an anomalous tissue, nor, on the other hand, as an accidental covering; but as a peculiar organ, composed of cellular tissue, the cellules of which are flattened and very firmly joined together.

The cuticle is obviously intended for the protection of the more delicate tissues it encloses, and to restrain the evaporation. To enable it to perform these offices, its structure varies with the influences to which the plant is exposed. Thus, in the leaves of plants which grow in damp and shady places, the cuticle is thin and soft, and the evaporation consequently copious; whereas in those plants which are exposed to the extremes of heat and dryness, it is thick and firm so as to restrain evaporation in a considerable degree; while the nearly impermeable cuticle of succulent vegetables prevents it almost wholly, and thus effectually induces their peculiar condition. The leaves of submerged aquatic plants, from which evaporation cannot take place, have no cuticle.

The cuticle adheres more or less firmly to the subjacent tissue in different plants; in thick and leathery leaves it can with difficulty be detached; but in those of herbaceous texture, and especially in succulent plants, it may be raised with the greatest ease. Sedum Telephium (the Live-for-ever of gardens) and the House-Leek (*Sempervivum tectorum*) are good subjects for its examination. Some recent observations of Brongniart and Prof. Henslow render it probable that there is stretched over the true skin, and closely adhering to it, a very thin and transparent pellicle, which exhibits no trace of organized structure. Its use is unknown, and its existence is, doubtless, confined to Flowering plants.

16. The cuticle is commonly furnished with a great number of minute oval holes, which have received the name of *stomata* (*fig.* 13.). Lindley calls them also breathing-pores, which is a very appropriate term. The cuticle of a leaf exhibits them best, and here they are always placed over some part of the green pulp, and not upon the veins. They are situated directly over a little cavity with which several intercellular passages (13) communicate; so that when the breathing-pore opens, the air has free access to the parenchyma or pulpy part of the leaf. A breathing-pore is not a simple hole in the cuticle, but it has a peculiar apparatus

at its orifice, "constructed," as Prof. Lindley observes, "of two little oblong bladders placed parallel with each other, and having the power of contraction or expansion as circumstances may require. When at rest, they are perfectly parallel, and by pressing their sides together, close up the opening; when in action, they curve away from each other in the middle, and thus leave the passage open." *Fig.* 13, *b*, (also borrowed from Lindley,) sufficiently explains this contrivance for opening and shutting the breathing-pores. It represents two stomata, one of which is closed (*fig.* 13, *b.* 1.) and the other open. This curious border, which controls the breathing-pore, is very hygrometric, contracting by moisture so as to shut the orifice, and spreading again in sunshine or dry air. The form of the breathing-pore depends upon the number of the vesicles which compose its border. There are usually only two, and the stoma is oval. Sometimes there are four, in which case it is round or square.

Stomata exist, with a few exceptions, in the leaves and other green parts of all Flowering plants, but not in roots or underground stems. In aquatic plants, they are never found in those portions that are habitually under water. They are most abundant in the cuticle of leaves and of young and growing stems, but they have also been detected in all the parts of the flower.

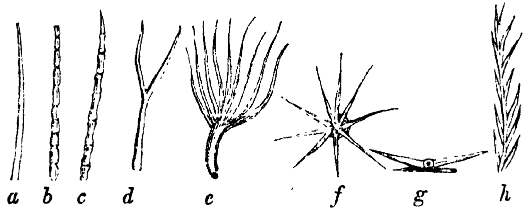
In some cases, breathing-pores are equally numerous on both surfaces of a leaf; they are rarely confined to the upper surface, as in the grasses, and the floating leaves of the Water-lily; but they are usually most abundant on the lower surface of leaves.

In succulent plants, such as the Prickly-pear and Ice-plant, the breathing-pores are nearly all closed up. It is to this cause and to their thick and firm cuticle, restraining evaporation so that they are unable to get rid of the superfluous water they take in by their roots, that their succulence is principally due. Stomata do not exist in true parasitic plants, such as the Dodder, Orobanche, &c., which never become green. It is stated, also, in most elementary books, that they are found in no Flowerless plants, excepting the Ferns; but they have recently been detected in Mosses, and in the Hepaticæ or Liverwort tribe. The stomata of Marchantia polymorpha are admirably illustrated by Mirbel.

It is by means of these breathing-pores, that leaves and the leaf-like parts of plants exhale and inhale air. Their office is therefore nearly the same as that of the spiracles or breathing-pores of insects. They also assist materially in evaporation.

17. HAIRS (*Lymphatic hairs* of De Candolle) are very slender, elongated portions of the cuticle, which are more or less abundant upon the surface of many plants, forming what is called *pubescence*. Their true structure cannot usually be ascertained by the naked eye, but an ordinary microscope is sufficient for their examination.

Fig. 14.



Hairs often consist of a single attenuated cellule, when they are said to be *simple*, as in *fig*. 14, *a*. Sometimes they are composed of several cellules placed end to end (*fig*. 14, *b*. *c*.), when they are called *jointed* hairs. Of this kind are the long, blue hairs with which the stamens (122) of the Spider-wort (*Tradescantia*) are furnished (*fig*. 14, *b*.). They are made of numerous oval cells strung together in a single row, and have a strong resemblance to the antennæ of some coleopterous insects. Those of Xanthium spinosum, with a high magnifying power, have the appearance of a bamboo in miniature (*fig*. 14, *c*.). It often happens that several hairs grow together at the base, spreading towards the extremity, forming *branched* or *compound* hairs. In some cases they are two-forked, as in *fig.* 14, *d;* they are three-forked in several Cruciferous plants, and many-forked (*fig.* 14, *e.*) in some of the Mallow tribe. They are said to be *stellate* or *star-shaped* (*fig.* 14, *f.*) when several hairs arise from the same point, and spread in every direction. Such hairs are seen in Sida, and other plants of the Mallow tribe. Sometimes two hairs start from a little elevation of the cuticle, and point in opposite directions, when they have the appearance of a single hair fixed by its middle (*fig.* 14, *g.*); such hairs are seen in all the species of the Indigo-plant, and also in the Shepherd's purse. Hairs which are furnished with several shorter ones on their sides, as in *fig.* 14, *h*, are said to be *toothed.* When the branches are still longer, they are said to be pinnate; and when the branches are divided in the same manner, they are said to be *plumose.*

Every part of a plant which is exposed to the air may bear hairs, but they commonly abound upon young stems and leaves. They are, almost without exception, more abundant on the lower than the upper surface of leaves. Their situation in leaves is always upon the frame-work or veins and their ramifications, and not upon the parenchyma. Subterranean stems and those which grow under water are always destitute of hairs. Young leaves and fruits are more thickly clothed with hairs than the same organs fully grown. The pubescence frequently falls off during their growth, as in the leaves of the Horse-chesnut and Poplar; but sometimes the growth of the organ merely spreads the pubescence over a greater surface, and thus renders it more sparse.

The flower is sometimes provided with a peculiar kind of pubescence; the hairs have the same color as the organ to which they belong, and are protrusions of its substance, and not simple appendages of the cuticle. The inside of the petals of Menyanthes, and the stamens of the Spider-wort and Mullein, furnish examples of this kind of hairs.

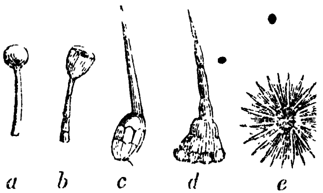
Little is certainly known concerning the use of pubescence. It has been considered as a provision for facilitating evaporation by increasing the quantity of exposed surface; and this view is rendered plausible from the familiar fact that hairs are wanting in succulent plants, which lose scarcely any thing by evaporation, while, on the other hand, they are often abundant upon plants which evaporate greatly. Their situation upon the frame-work of the leaf, however, does not seem to adapt them to this purpose; and, besides, abundant provision is otherwise made for evaporation. Some writers think that the office of hairs is to absorb moisture from the atmosphere; a view which is liable to the same objection as the foregoing one. The opinion of De Candolle, which is on the whole most probable, is, that pubescence serves to protect the surface against the effects of excessive heat or moisture, and to restrain, in some degree, evaporation from the breathing-pores. According to this view, the office of pubescence in plants is very similar to that of the hairy covering of the skins of animals. The absence of hairs on the leaves of succulent plants, in which the stomata are mostly closed up, and their abundance on the lower surface of most leaves (the surface most liberally furnished with breathing-pores), is highly favorable to this view.

When hairs grow on the margins of any organ so as to form a fringe, like the eye-lashes, they are called *ciliæ*. Stiff and strong hairs are called *bristles*. Bristles curved near the point, as in the fruit of the Burrdock and Clott-burr(*Xanthium strumarium*) are called *hooks*. They are called *barbs* when their apex is furnished with two short hooks (as in the fruit of Echinospermum Lappula), or with two sharp processes pointing backwards like the barb of an arrow, so that when they pierce the skin they are with difficulty withdrawn.

The different kinds of pubescence, with the names by which they are distinguished, will be noticed in the chapter on Glossology. It may here be remarked that, while the degree of pubescence is of little consequence in systematic botany, its kind furnishes excellent characters for distinguishing species.

18. **Glandular Hairs** have a more complicated structure than ordinary hairs. Two distinct kinds of apparatus have been confounded under this name, viz: proper glandular hairs, or rather stalked glands, and stings. True *glandular hairs* consist of little bodies, called glands, which are capable of producing a peculiar volatile, aromatic, or glutinous fluid, placed on the summit of stout hairs. They abound on the leaves of the Sundew, on the flower-cup and stalks of the Fraxinella of the gardens, and the Rose (*fig.* 15, *a.*). In the common Butternut (*fig.* 15, *b.*) the gland is an open cup, filled with a glutinous and bitter fluid.

Fig. 15.



Similar bodies, which are not mounted upon hairs, are called *sessile* glands. The stem of Polanisia graveolens exhibits them quite well.

Stings (*fig.* 15, *c, d.*) are rigid, sharp-pointed, and tubular hairs, which stand upon a peculiar kind of gland, and serve as the outlet of the irritating fluid they produce. The structure of stings is very curious. Those of the Nettle (*fig.* 15, *c.*) consist of a large gland, filled with an acrid and poisonous liquor, surmounted by a sharp, hollow bristle, from the point of which the fluid exudes when the poison-bag is pressed upon. The effects of the venomous sting of the common Nettle are too well known; but they are not to be compared with those of some East Indian species, which have been known to produce, not only the most excruciating sufferings for several days, but violent fever, with lock-jaw and other dangerous symptoms. In the Gourd (*fig.* 15, *d.*) the bristle is jointed, and the liquor of the gland is but slightly irritating. Stings are evidently organs of defence. In their structure and office they are strikingly similar to the fangs of venomous serpents.

19. **Scales**, (*fig.* 15, *e.*), which give the peculiar scurfy appearance to the leaves of Atriplex arenaria,

Shepherdia Canadensis, and most species of Croton, are of the same nature as hairs, and are usually fixed to the cuticle by their middle. In the examples referred to, each scale is a bunch of stellate hairs, which have grown together into a single body.

20. **Prickles** are conical, sharp-pointed processes of the cuticle and cellular integument beneath it. They have neither woody fibre nor vessels in their composition, and consequently may easily be broken off. In this respect they differ from spines, which belong to the woody and vascular tissues. Prickles may exist upon almost every part of a plant; those of the stems of the Rose and Gooseberry, and of the fruit of the Stramonium, are very familiar examples. When young they are soft and green; as the stem increases in diameter they enlarge at the base, and finally harden, when, if the stem continues to grow, being no longer able to accommodate themselves to the expanding surface, they soon fall off. This is the reason why the young branches of the Gooseberry and Raspberry are prickly, while the older ones are nearly unarmed. Prickles do not differ essentially from bristles: they are not inaptly characterized as "hairs of a larger growth."

21. De Candolle has given the name of *Lenticels* to the brown spots that are found upon the cuticle of the Willow, the Birch, and most trees and shrubs of this climate. When they first make their appearance, they are oval spots with their largest diameter parallel with the stem; but by the distention of the cuticle, as the branch increases in diameter, they become round, and finally elongate horizontally. From these points roots make their appearance in a few days, when a cutting of Willow, &c. is planted, or is kept in water.

Sect. II. *Of the Root.*

22. When a seed is placed in the ground under circumstances which favor its development, the embryo plant contained within it begins to grow, and to increase in length in two opposite directions; one of its extremi-

ties is always turned upwards toward the light and air; the other as invariably takes a downward direction, and buries itself in the earth. The portion which elongates upwardly, is the *ascending axis* or *stem;* and that which extends downwardly, forms the *descending axis or root.* The point from which these two opposite elongations start, or, in other words, the line where the root and stem join, is called the *collet* or *neck*. At this early period of the plant's existence the neck is usually distinctly visible, but after a while it becomes merely an imaginary line of separation between the base of the stem and the base of the root.

As this double elongation takes place in the germination of all seeds, it follows of necessity, that all plants produced from seeds must have, during their early growth at least, both a stem and root. The few exceptions to this rule are rather apparent than real, and do not affect its truth. Thus, the Dodder and all similar parasitic plants are furnished with true roots in early life; but when they have fixed their suckers upon neighboring vegetables, so as to draw from these their nourishment, their roots, being no longer needed, wither away. The same remark may be applied to the aquatic plants which float upon the surface of stagnant water; none of these are rootless from the beginning (excepting the Algæ or Sea-weeds); and many, like the Lemna or Duck-weed, are provided with roots during their whole existence, although they do not serve, as in most cases, to fix the plant to the soil.

23. The root has been defined to be the subterranean stem, or that part of the trunk which fixes the plant to the soil and burrows beneath its surface. This definition is quite defective, and leads to some erroneous conclusions; for while many roots are not at all connected with the earth, the true stem, on the contrary, is often in part, and not unfrequently entirely, subterranean. The principal distinction between the root and the stem is to be found in the difference of the direction of their growth. In structure they differ in this, that, as a general rule, roots have neither breathing-

pores, spiral vessels, pith, nor buds. To the first of these characters there are no known exceptions. The roots of most Endogenous plants (33), however, are provided with pith, and spiral vessels have recently been detected in several plants of the same class; but Exogenous plants have annular ducts in place of spiral vessels. and the pith, which usually abounds in the stem, always terminates abruptly at the neck. Roots do not give rise to buds and leaves under ordinary circumstances; consequently they present neither scales which are the rudiments, nor scars which are the vestiges, of leaves. Commonly, also, the bark of roots does not become green by exposure to sunlight.

Roots do not form branches in any regular order; the branches of stems, on the contrary, are more or less symmetrical, being produced by the development of buds which have a regular arrangement. The principal increase of roots in length takes place at their lower extremities; growing stems, on the other hand, elongate throughout their whole extent.

Although no roots are originally furnished with buds, yet those of several trees and shrubs are capable of producing them under peculiar circumstances. It is well known that when the trunk of a Poplar is cut off near the ground, those roots which spread just beneath the surface produce buds, and a multitude of young shoots make their appearance. The great accumulation of sap in the root gives rise, in such cases, to irregular or adventitious buds (44).

As roots are sometimes capable of producing stems, so, on the other hand, stems not unfrequently give rise to adventitious roots. Most creeping stems produce them at every joint, or wherever an accumulation of sap takes place. The branches of many shrubs, when they are bent to the ground and covered with earth, send out roots, and are then capable of growing as separate individuals. By taking advantage of this circumstance we are enabled to multiply many plants by division. Such roots are sometimes given off high in the air from the stems, and even from the leaves of a great number of woody and climbing plants of tropical countries.* They are very slender, and do not increase in diameter until they have reached the ground, and to effect this they not uncommonly attain the length of eighty or a hundred feet. The stems of Indian corn often produce these aerial roots from their lower joints.

Duhamel and other of the older botanists, to whom these facts were familiar, were in the habit of making a singular but somewhat hazardous experiment, upon those young trees which are capable of producing adventitious roots, such as the Willow and Poplar. They bent the trunk so as to bring the extremity of the branches to the ground, and when they had taken root and established themselves in their new situation, they were wholly covered with earth, while the true roots were uncovered and elevated into the air, and thus the tree was turned topsy-turvy. The roots, adapting themselves to their new situation, produced leaves, while the former branches took the place of roots. These experiments, however, by no means establish the point they were designed to prove, viz. : that roots and branches are mutually convertible into each other. Branches are not changed into roots when buried in earth ; neither are roots converted into branches by being elevated into the air; but in these cases the buried branches give rise to adventitious roots, while the roots, detached from the soil in which they grew, form adventitious buds.

24. The root commonly has a caudex or trunk, from which proceed several slender branches or fibres, by whose extremities nourishment is absorbed from the soil. These blunt extremities are composed of lax cellular tissue and the open mouths of ducts ; they are called *spongioles* or *spongelets*. That roots absorb fluid solely by means of these spongelets Sénebier proved, by a simple experiment, which is easily repeated. He took two young radishes from the ground with their stems and leaves ; one was so placed

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* *Examples*, Ficus elastica and all the species of Rhizophora.

that its apex only dipped into water; the whole root of the other was plunged beneath the same fluid, excepting the apex, which was exposed to the air. The leaves of the former remained fresh for several days, but those of the latter soon began to wither, and only recovered their freshness when the extremity of the root was immersed.

It should be remarked, that the base of the root is the extremity which is applied to the base of the stem, and the opposite extremity is the apex.

Fig. 16.

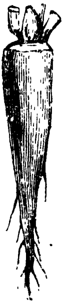


Fig. 17.

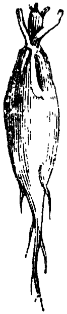
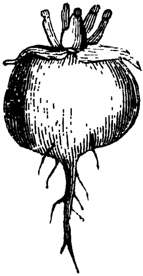


Fig. 18.



When the caudex is unbranched and tapers regularly from the base to the apex, as in the Carrot, it is said to be *tap-rooted* or *conical* (*fig.* 16.). When a conical root tapers at the base also, as in the Radish, it is called *fusiform* or *spindle-shaped* (*fig.* 17.) When the caudex is much swollen at the base and tapers abruptly below, as in the Turnip, it is said to be *napiform* (*fig.* 18.). Sometimes instead of a single caudex, the root is made up of several distinct portions which are joined to the base of the stem. When these divisions are slender and thread-like throughout their whole length, the root is said to be *fibrous* (*fig.* 19.). If these fibres are more or less swollen in the middle, they produce a *fasciculated* root (*fig.* 20.), as in the common Pæony of the gardens, and

Fig. 19.

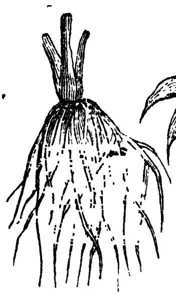
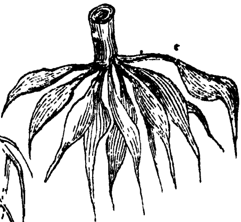


Fig. 20.



several species of Orchis. The gradual passage of fibrous into fasciculated roots, may be very finely seen in several common species of the Ranunculus or Crowfoot genus; for example, in R. recurvatus and R. fascicularis.

Occasionally the root bears one or more tubers, which are knobs or thickened portions, filled with starch, and intended, in all probability, as reservoirs of nourishment. Such roots are termed *tuberous* or *tuberous* roots. They are very common in the Orchis tribe (*fig.* 21.); in which the tubers are sometimes *palmate*, or deeply divided, like the hand with the fingers extended (*fig.* 22.). Tuberous roots should not be confounded, as they frequently have been, with true tubers or bulbs, such as the onion and the potato; of which the former is a subterranean bud, and the latter a modification of the stem.

Fig. 21.

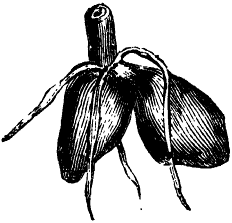
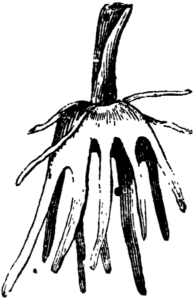


Fig. 22.



The office of roots is to fix the plant to the earth, and to absorb from the soil, and transmit into the stem, food for its support.

25. It has been ascertained by some highly interesting experiments, that the roots of many plants continually deposit in the soil a particular matter, the nature of which is uniform in each species. Thus, the Pea leaves a gummy substance in the earth it grows in; the Euphorbias a kind of gum-resin, of the same acrid nature as the milky juice of these plants; while the

Lettuce and the plants allied to it, as well as the Poppy, deposit a substance which has the taste and odor of opium. There is good reason to believe, that in this way plants not only eliminate a portion of their own peculiar secretions, but also rid themselves of any useless or deleterious substances they may have taken into their system. The whole subject is of great interest to the agriculturist as well as to the botanist. It offers a plausible explanation of the well-known fact, that some vegetables materially injure, and even destroy, other species in whose vicinity they happen to grow ; not so much, it would seem, by appropriating to themselves an undue portion of the common nourishment, as by the positively deleterious effects of their excretions upon the plants in their vicinity. It is also a circumstance familiar to every botanist, that some species appear to prefer each other's society, and are almost invariably found in company, in their native situations. In these cases it is probable that one plant is nourished in part by the excretions of the accompanying species. The soil in which a single species has vegetated for a long time becomes, as cultivators well know, deteriorated for that species ; not because the soil is exhausted, for some other plants will grow in it extremely well, but for the reason, that the excretions of any plant are injurious to other individuals of the same kind. Thus M. Macaire found that kidney-beans languished when fed with water in which individuals of the same kind had been raised, but wheat watered with the same fluid flourished and grew more rapidly than when supplied with pure water. These facts, without doubt, furnish us with the true explanation of the *advantages of a rotation in crops.**

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* Those who take an interest in this curious subject will do well to consult De Candolle, *Physiologie Végétale*, pp. 248, 1474, & 1503 ; also a memoir of M. Macaire in the Memoirs of the Society of Natural History of Geneva, vol. 5.

SECT. III. *Of the Stem.*

1. OF ITS EXTERNAL MODIFICATIONS.

26. THE STEM is the part which grows in an ascending direction when a plant is raised from the seed. To it belongs every thing that intervenes between the root and the leaves. While the root, avoiding the light, inclines to bury itself in the earth, the stem has a strong tendency to rise in the opposite direction, so as to expose itself as much as possible to the light and air. At the commencement of its growth, the stem always takes an ascending direction; but subsequently it often extends horizontally, either upon or beneath the surface. Sometimes, indeed, it remains entirely under ground during the whole life of the plant, and continues to increase in size without extending in any particular direction. Stems of this kind were mistaken for roots by the earlier botanists, as they still are by persons who are not botanists. All Flowering plants have stems in some form or other. Those which have conspicuous stems are said to be *caulescent;* and, in contradistinction to these, plants which are provided with an inconspicuous or subterranean stem only, are called *acaulescent* or *stemless* plants. It would be more correct to say of such plants, that they are *subcaulescent,* for they are in no case really stemless.

27. During the growth of the stem, its elongation is momentarily checked at certain intervals, by which narrow portions are rendered more firm than the other parts of the stem. No explanation has been offered concerning the cause of this periodical interruption. The firmer portion which results from it is termed a *node;* and the space which intervenes between two nodes is called an *internode.* Nodes exist, under some form, in all stems, and are situated at regular distances from each other. They are, in numerous cases, entire rings, as in the Elder, in the stems of Grasses, the Bamboo, &c., in which they are usually, but improperly, called joints. They have not the nature of joints, for

there is no tendency to a separation at these places, but rather the contrary.

Often this momentary interruption takes place at particular points, and not around the whole circumference of the stem. In such cases no ring is formed, but the nodes are said to be *divided.* Examples of this kind are seen in the Apple-tree and in all plants with alternate leaves (60).

It is worthy of especial notice respecting nodes, that from these (and, except in extraordinary circumstances, from these only) all buds, and consequently all leaves and branches, originate. Buds (42), which are nothing more than branches in miniature, are always called into existence by the growth of the stem; and in turn they exert an important influence upon its increase, the nature of which will be better understood in another place. As buds always arise from nodes, and as nodes are produced at regular intervals along the stem, it follows that branches should always be symmetrical. They really are so in many plants; and the reason why this symmetry is not always to be observed, is, that only a small portion of the existing buds grow into branches, and the remainder are destroyed, by various causes, at an early period.

28. Those stems which, every year, either perish entirely, or die down to the ground, leaving a subterranean stock from which new shoots arise, are said to be *herbaceous.* Those which endure for an indefinite period are called *trees* when they have a single trunk which exceeds by five times or more the height of a man; *shrubs*, when they are of lesser height and branched near the ground; and *undershrubs*, when they are intermediate in texture and duration between the shrub and herb.

The stem or straw of grasses Linnæus distinguished by the name of *culm;* a term which it is often convenient to use, although a culm does not differ very materially from an ordinary stem.

Stems which have too little strength to stand erect, often support themselves by adhering to neighboring bodies. These are called *Climbers.* The Vine, the Passion-flower, &c., climb by means of tendrils (63), and the Virgin's-bower (*Clematis Virginiana*) climbs by its leaf-stalks. Numerous stems coil spirally around the stems or other objects within their reach; these are *voluble* or *twining* stems. Each species twines with uniformity, either from right to left, or from left to right; but the cause of this, or even of their twining at all, is wholly unknown.

A *Runner* is a prostrate and slender stem, sent off from the base of a parent stem, which roots and produces leaves at its extremity. In this way a young plant arises, capable of existing apart from the original stem, and of extending itself in the same manner. The runners of the Strawberry are the most familiar examples.

A *Sucker* is an erect branch from the subterranean portion of a stem, which first produces leaves, and afterwards gives rise to roots, when it becomes an independent plant.

A *Stolon* is a branch from the lower part of a stem, which falls to the ground and takes root.

An *Offset* is a short prostrate branch, terminated by a tuft of leaves and capable of taking root, as in the Houseleek.

These are the principal varieties which the stem assumes when it rises above the surface of the ground. Its subterranean modifications are so peculiar that they require a separate notice; the more so because they were for a long time confounded with roots, from which it is important that they should be distinguished. The most common of all these forms is,

29. The Rhizoma or *rootstock* (*fig.* 23.), a prostrate stem which elongates and produces leaves or branches from its anterior extremity, and roots from any part of its surface. It may be either half-buried in the soil, as in the common garden Iris, and the huge prostrate trunks of the Water-lily; or entirely subterranean, as in the Acorus Calamus or Sweet-flag, and numerous other examples.

The rootstock increases in length from year to year by its anterior extremity, and at the time, as large a portion of its older or posterior extremity perishes; from this circumstance, perhaps, it has been called a *progressive root.* This kind of growth, however, will serve to distinguish them from roots, which elongate in the opposite direction, and by the extremity the most remote from the stem and leaves. Rootstocks, moreover, are marked with scars or scales, the vestiges of leaves, from the axils of which buds often arise: roots are not furnished with scales, and are incapable of producing buds. The *scaly roots* of the old botanists are therefore varieties of the subterranean stem: they are rootstocks, clothed with the thickened and adherent bases of former leaves, as is seen in Hydrophyllum Canadense (*fig.* 24.).

Fig. 23.

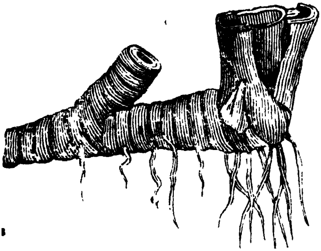
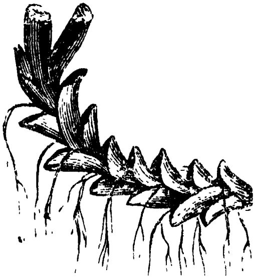


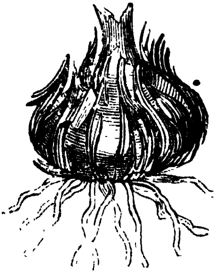
Fig. 24.



True creeping roots are sometimes seen, but this name has more frequently been applied to those stems and branches which creep below the surface of the ground. Of this kind are the roots, as they are incorrectly termed, of the Mint, of the Couch-grass (*Triticum repens*), and of Cyperus Hydra, that scourge of the planters in the Southern States. These subterranean branches are extremely vigorous, and often extend to a great distance in the soil, which they occupy to the exclusion of other plants. They are very tenacious of life, being furnished with buds at every node. Thus constituted they are the great enemies of the agriculturist, and some of them are absolutely indestructible by the ordinary operations of husbandry; for when torn in pieces by the plough, each portion is placed in the most favorable circumstances for the development of its buds, and some fifteen or twenty individuals spring up in the place of a single branch. Creeping roots, on the contrary, rarely give the cultivator trouble, as (excepting a few species which very readily produce adventitious buds) they perish when the stem is destroyed.

30. The **Cormus** (*fig.* 25.) is a roundish stem, which remains underground, but does not extend in any particular direction. From its upper surface branches or leaves arise, and at its base it sends out fibrous roots. Examples of the cormus are found in the Crocus, the Tulip, and the Indian Turnip (*Arum triphyllum*).

Fig. 25.



31. **Tubers** are short and thickened portions of an underground stem, furnished with several buds, which by their growth produce new individuals. The Potato

Fig. 26.

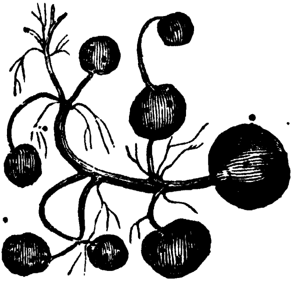
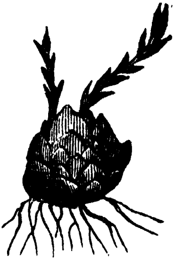


Fig. 27.



is one of the best and most familiar examples of this kind of stem (*fig.* 26.). Its tubers are portions of subterranean branches, very much enlarged by the accumulation of a quantity of starchy matter around several buds, or, as they are usually called, eyes. Inspection during their forming state renders it evident, that potatoes are borne upon short branches, and not upon the root as is commonly supposed. Consequently, to produce them in considerable quantities, it is necessary to heap the earth around the lower part of the stems, to the end that the number of subterranean branches may be multiplied. These branches are slender and of the same diameter throughout, when they first make their appearance. After a while they suddenly cease to elongate, and the nutritive matter, accumulating in their extremities, causes these to enlarge, and the deposition of starch in their tissue continues this enlargement until the full-grown tuber is formed. By particular management, potatoes have been made to form upon the ordinary branches of the plant, and in the axils of the leaves.*

Small tubers are called *tubercles*. *Granulated roots*, as the older botanists termed them, are in some instances scaly rootstocks, as in Wood-sorrel (*Oxalis*); and in other cases, clusters of tubercles growing at the base of the stem, as in Dielytra Cucullaria † (*fig.* 27.), a delicate, early-flowering plant of the Fumitory tribe, with handsome cream-colored flowers, of a very bizarre appearance.

32. The Bulb (bulbous root of Linnæan botanists) is a very short stem, which bears a bud on its upper, and emits fibrous roots from its lower, surface (*figs.* 28 *and* 29.). The structure of the bulb is similar to that of an ordinary leaf-bud, except that, being produced beneath the surface of the ground, the scales or imperfect leaves which envelop it are usually somewhat thickened and fleshy. It must be kept in mind, there-

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* De Candolle, *Physiologie Végétale*, I., p. 156.

† Corydalis Cucullaria of *Persoon* and *Pursh*.

Fig. 28.

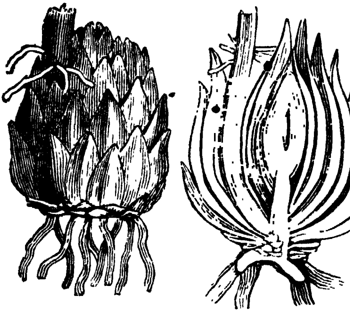
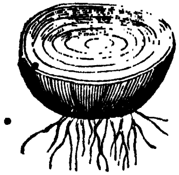

a. *b.*

Fig. 29.



fore, that a bulb is a subterranean leaf-bud, although it is more convenient to notice it here among the modifications of the stem. There are two kinds of bulbs:

1st. The *naked* or *scaly* bulb, in which the scales are fleshy and distinct or cohering at their bases only, as in the Lily (*fig.* 28, *a.*). *Fig.* 28, *b.* represents a longitudinal section of the same bulb, and exhibits the bud, or growing portion, the development of which forms a stem.

2d. The *tunicated* bulb (*fig.* 29.), as in the Onion, in which the scales surround the bud, forming a distinct covering of several layers. The innermost layers are commonly fleshy, and the outer ones dry and membranaceous.

Bulbs are not always found beneath the surface of the soil: they are sometimes produced on ordinary branches, or even upon leaves. A common variety of the Onion, and several plants of the Onion tribe, bear them instead of flowers. The Orange-lily, a very common plant in our gardens, produces bulbs in the axils of the leaves, which when full grown spontaneously separate from the stem, and fall to the ground, where they take root.

In many botanical works mention is made of *solid* bulbs. Such bulbs, it is evident, can have no existence. They are in some instances tubers, but are commonly examples of the cormus. *Ex.* The Tulip and Crocus. Some authors term them *bulbo-tubers.*

2. Of its Internal Structure.

33. There are two principal modifications of structure in the stem of Flowering plants. Some stems are made up of three distinct parts, viz.: bark, wood, and pith; of which the pith always occupies the centre, the wood is placed in regular layers around the pith, and is intersected by very thin plates of cellular tissue, which radiate from the centre to the circumference; the bark surrounds and encloses the whole. Such stems increase in diameter by the regular addition of new layers to the outside of the old wood; whence all plants whose stems are thus constructed, are called Exogenous plants, or, as the name denotes, growers outwardly.

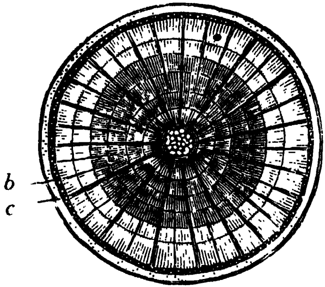
Other stems occur in which there is no distinct bark, woody layers, or pith, but bundles of woody fibre and vessels are imbedded, seemingly without regular order, in a spongy tissue; the oldest portions being at the circumference, and the newly-formed bundles near the centre. Plants with this kind of stem have received the name of Endogenous plants, or growers inwardly. The principal peculiarities of these two kinds of structure will be comprehended at once by the inspection of a branch of the Oak, Maple, or of any other tree of this climate, and a piece of cane or rattan; the former are examples of the Exogenous, the latter of the Endogenous, mode of growth. They require to be separately considered; and as the former is most familiarly known, and has received the attention of botanists in a much greater degree, we shall commence with,

I. *The Exogenous Structure.*

34. A transverse section of an Exogenous woody stem (*fig.* 30.) always presents the following arrangement. The *pith*, a light and spongy cellular substance, occupies the centre. This is surrounded and enclosed

by a thin layer of spiral vessels with some woody fibre which forms a complete sheath or casing for the pith; hence it is termed the *medullary sheath.* Next in order to the medullary sheath, and making up the principal bulk of the stem in shrubs and trees, is the *wood;* which is composed of cellular tissue, woody fibre, and ducts. The number of concentric rings or circles, presented by a cross-section of the wood, is an accurate index of the age of the stem, a new ring of wood being formed every year. The newest woody layer is formed on the outside of the existing wood and next to the bark; the earlier layers remaining near the centre of the stem, wholly undisturbed by its future growth.

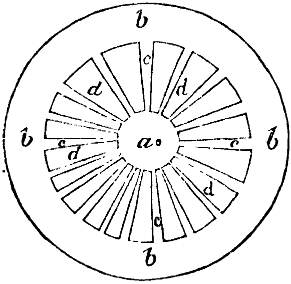
Fig. 30.



The numerous fine lines which radiate from the pith to the surface of the wood, are the *medullary rays.* They are thin plates of cellular tissue which perforate the medullary sheath on every side, and pass through the wood quite to the bark, cutting it into a great number of thin wedges. In the accompanying figure they are purposely made more conspicuous than they really appear in a transverse section of the stem.

The *bark* is composed of two parts, viz.: an inner portion called the *liber* (*fig.* 30, *b.*), which consists of cellular tissue with woody and vascular tissue intermixed; and an outer cellular portion, which is green in young stems, termed the *cellular integument* (*fig.* 30, *c.*). The bark is covered, at least in young stems, by the thin transparent membrane which invests the whole of the vegetable, viz.: the cuticle (15). The figure we have introduced to illustrate this subject, has the several parts more conspicuous than they exist in nature. It gives a sufficiently clear view of the relative situation of these parts in an Exogenous stem. The structure of the stem, however, may be still better understood by considering it as the result of the intimate union of two distinct systems, viz.: the cellular system, which is composed of cellular tissue only; and the fibro-vascular system, which consists of woody fibre and vessels. The cellular system is, for the most part, the earliest formed; it is the matrix in which the fibro-vascular system is deposited. To it belong the pith, the medullary rays, and the cellular integument; parts which are, consequently wholly formed of cellular tissue. Their arrangement previous to the introduction of the fibro-vascular system, is shown by the annexed diagram (from Lindley's Introduction to Botany), in which *a* represents the pith, *b* the bark, and *c* the medullary plates (*fig.* 31.). This system is seen to occupy principally the centre and circumference of the stem, the medullary plates serving to connect the two portions together.

Fig. 13.



35. The *pith*, or *medulla*, is a cylindrical column of spongy cellular tissue, which commences at the neck of the plant, and extending through the axis of the stem and branches, terminates at the buds. Its size compared with the wood is variable; herbs and young shrubs in proportion to their bulk have more pith than trees; but the diameter of the column, when once formed, never changes. In newly-formed parts the pith is juicy, being saturated with the ascending sap; in the same stems when old, it is dry, colorless, and very light. At first it is an unbroken column, and commonly it continues to be so during the life of the plant; but in some cases it is broken into several portions, or torn by the rapid elongation of the stem, so as to leave irregular cavities, as is seen in the Walnut and Horse-chestnut. By the great increase in diameter

of many herbaceous stems, the pith is torn into shreds, leaving in its place a large cavity lined with its remains. The column of pith is not interrupted at the nodes, but is rendered more compact.

Respecting the office of the pith many singular opinions were formerly entertained. Among other views, which it would be useless to detail here, some of the earlier botanists maintained its office to be analogous to that of the nervous system in animals. This opinion was recently revived, in a somewhat modified form, by Dutrochet. The analogy in this case is overstrained, and no observations have proved the pith to be endowed with any property which is not common to the whole cellular system. If the cellular tissue of the stem possesses the properties of a nervous system, vegetables are certainly much more highly favoured in this respect than even the highest orders of animals!

So far as we know, the principal use of the pith is to furnish nourishment to the buds during their early growth. When no longer filled with the juices of the plant, it is of no apparent use.

36. The *medullary rays* or *plates* (*fig.* 31, *c.*) are thin vertical plates of cellular tissue, sent out in every direction from the pith to the circumference of the stem. In structure they are similar to the pith, except that the strong lateral pressure to which they are subjected by the interposed wedges of wood (*fig.* 31, *d.*), causes their cellules to take the shape of muriform cellular tissue (4. *fig.* 3.). In trees and shrubs the medullary rays appear on a transverse section as fine lines, radiating from the pith and intersecting the wood. Their office is to maintain a communication between the pith and bark; through these, the juices which descend in the bark are conveyed into the wood.

37. The *bark*, or *cortical system*, as it is sometimes called, exists in its simplest state in stems of a single year's growth. It consists of an inner layer of fibrous matter intermixed with cellular tissue, lying in immediate contact with the wood, but readily separable from it except at particular seasons, and an outer coating

of cellular tissue, colored green by exposure to solar light, over which the cuticle is evenly stretched.

The inner bark has received the name of *liber ;* either because in old stems it is made up of numerous layers like the leaves of a book, or because it was sometimes used for writing upon, previous to the invention of paper.

The outer spongy portion is called the *cellular* or *cortical integument,* and sometimes, but improperly, the epidermis. It is this part, developed in an unusual degree, that gives the peculiar swollen appearance to succulent plants; it also abounds in many edible roots; very much exceeding the woody portion in the Carrot, the Parsnip, &c. in which it is unnaturally developed by cultivation.

The bark increases in diameter by the deposition of a new layer every year between the original liber and the wood: each new layer is, as it were, a repetition of the first, consisting like it of an inner fibrous, and an exterior cellular portion; but the spongy portion being excluded from the light does not become green, as in the original cellular integument. That new layers are actually added to the bark internally, was first proved by Du Hamel, by a simple experiment which has often been repeated. He passed a metallic thread through the innermost layer of the liber of a young tree; and on cutting across the bark, several years afterwards, the wire was found to have been pushed outwards by the deposition, between itself and the wood, of new cortical layers, coinciding in number with the years that had elapsed since its introduction. As the bark grows by the successive addition of annual layers, it would appear that the age of a tree might be determined by counting these layers. This, however, can only be done in a young tree in which the cuticle and cellular integument remain entire. In old trunks the outermost and oldest layers are torn by the continual distention of the growing stem, and becoming dead matter, finally fall away. The duration of the bark varies in different species. In the Oak, the Elm, and in many trees of the Fir tribe, it breaks into deep longitudinal fissures as the stem increases in diameter, and attains the thickness of several inches, or even a foot, in some old trunks. On the other hand, a portion of the bark of the American Plane-tree* falls off every year in the form of brittle plates, and in the Birch it is separated into thin membranous layers, which have been mistaken for the cuticle. The liber possesses considerable strength, and is applied to many useful purposes. Mats and coarse cordage are made from the bark of Tilia (called in Europe Linden or Lime-tree, and in this country Basswood), and the bark canoes of the Indians are made from a species of Birch. The woody fibre which is used for the manufacture of cordage, in all Exogenous plants (as in hemp, flax, several Malvaceous plants, &c.), belongs to the liber and not to the stem. The bark, like the wood, is traversed by medullary rays, the extremities of which are in contact with those of the stem.

The bark is obviously intended for the protection of the young wood which is formed beneath it. It is also the medium through which the juices of the plant which have been elaborated in the leaves, descend and are transmitted to the wood; consequently the bark is absolutely essential to the life of an Exogenous plant. In herbs and in young branches where the bark is green and succulent, it performs the same functions as the leaves, which are in fact mere expansions of the bark; and it supplies their place whenever, as in the Cactus or Prickly-pear, true leaves are not developed.

38. The *medullary sheath* is the earliest formed portion of the vascular system; its growth is simultaneous with that of the pith which it encloses from the base of the stem to the extremity of the branches. The medullary sheath is an extremely thin layer of woody fibre and spiral vessels, and it is (a few anomalous instances excepted) the only portion of the stem in which spiral vessels exist. Although its particular uses are not well understood, yet this organ is

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* Platanus occidentalis, commonly called Button-wood or Sycamore.

known to be essential to the perfect development, and even to the life, of an Exogenous plant. The veins of leaves and flowers are prolongations of the medullary sheath.

39. The *wood*, which exists more or less abundantly even in herbaceous stems, and which constitutes so large a portion of trees and shrubs, may now be considered. Its arrangement in Exogenous stems will be understood by a reference to *fig.* 31, in which *d* represents the wood. We may consider it as made up of wedges of woody and vascular matter imbedded in the cellular system. The base of each wedge is in contact with the inner surface of the bark, the apex is next the pith, and its sides are bounded by the medullary rays. As the medullary rays are very thin and usually inconspicuous, we ordinarily speak of the wood as if it consisted of unbroken rings or circles.

An examination of a branch, the result of a single year's growth, will give a good idea of the structure of the wood. In such a branch it consists of a single zone or layer interposed between the pith and the bark, and lined internally by the medullary sheath. It is made up of woody fibre and ducts intermixed without apparent order, except that the ducts are most abundant on the side next to the medullary sheath. The ducts are usually of the kind called dotted ducts (*fig.* 5.); their open mouths are evident in transverse sections of pieces of Oak or Maple, giving the wood of these plants a porous appearance. In the Pine, and all Coniferous wood, ducts are entirely wanting.

The second year a new layer is formed on the outside of the first, similar to it in every respect, except that there is no medullary sheath within it; the succeeding year a third and similar layer is deposited on the outside of the second, &c.; a new layer being annually deposited as long as the plant lives. In some plants the woody layers are separated from each other by a thin layer of cellular tissue which probably proceeds from the medullary rays, but in most woody stems these interposed cellular zones are not evident. A new layer is added to the wood and to the bark at the same time and in the same manner, although the new zone of bark is added on the inside, and that of the wood to the outside, of the old formation. The outer layers of the bark, however, being distended by the deposition of new zones within them, as well as by the increase of the stem itself, are continually destroyed from without, where they are exposed to the influence of the air and other external agents. The woody layers, on the contrary, being subjected to no distending force from within, and protected from external agents by the newly formed zones, remain unalterable except from disease, during the life of the plant. Inscriptions upon the bark of a tree finally disappear in consequence of the gradual destruction of the oldest layers, and foreign substances deposited in its substance are subsequently brought to the surface for the same reason. Foreign matters introduced into the wood, however, remain as long as the wood endures.

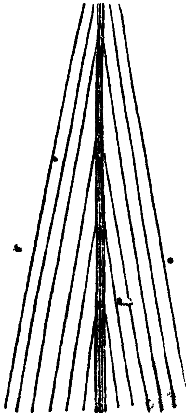
The annual rings of wood may be distinguished with ease upon transverse sections of the trees and shrubs of temperate climates, or wherever there is a suspension of vegetation during a portion of the year; those of tropical countries have them indistinctly marked.

These rings, moreover, are not always of equal thickness in the same tree; for the quantity of wood formed in each season varies according as the season is more or less favorable to vegetation, and is also influenced by many local circumstances. In old trees, however, the rate of increase is remarkably uniform in each species. The individual rings are occasionally thicker on one side of the tree than the other; or, in other words, the tree grows fastest on one side, so that the pith is not unfrequently at some distance from the geometrical centre of the trunk. This is owing to several causes, such as more favorable exposure, or the greater development of roots on one side. Other things being equal, wood is formed in the greatest quantity upon the side of the tree which develops the greatest number of branches; the reason of this will be hereafter explained.

There is almost always a marked difference in color and density between the old and the recent wood; the outer or newest portion, which is always white and more or less juicy, its vessels being filled with sap, has been called in allusion to its color, the *alburnum*, or by workmen, the *sap-wood.* After a few years, the color of these layers is gradually changed, beginning with the innermost; their density increases, and they take thereafter little part in the transmission of the sap. These rings of perfectly-formed wood are called the *heart-wood.* The change is owing to the deposition of a solid matter peculiar to each species, in the cellular tissue which is intermixed with the woody fibres. If a piece of heart-wood be digested for some time in weak nitric acid, this matter is dissolved, and the wood again becomes colorless. The heart-wood is always preferred by workmen, as it is stronger, more durable, and less readily affected by moisture than the alburnum.

In most trees the change in color is sudden and well marked, as in Hickory, Black-walnut, and especially in the Ebony, in which the alburnum is white and the heart-wood black. The heart-wood not uncommonly includes a greater number of rings on one side of a tree than the other.

Fig. 32.



The wood of an Exogenous stem of a single year's growth, may be viewed as an elongated hollow cone, extending from the base to the summit of the stem, and enclosing the pith. This cone does not extend farther, but is the next season surrounded by a similar cone, which, like the first, does not afterwards elongate or increase in thickness. Each succeeding year a similar hollow cone of wood is formed and deposited around the older portions, extending beyond them in length. Hence, as a necessary result of this mode of growth, the trunk of an Exogenous shrub or tree is conical. We have attempted to show this by the annexed diagram, (*fig.* 32.) which represents a longitudinal section of a portion of an Exogenous woody stem. It will be recollected that the root is formed upon the same plan, except that it wants the pith : it is likewise conical, but in an inverse sense, the base of the root and the base of the stem being applied to each other at the neck.

As each layer, or, to speak more correctly, hollow cone of wood, is the result of a single year's growth, it is evident that the age of an Exogenous tree may be ascertained by counting the rings which are presented on the transverse section of the trunk near its base. This may be done with great accuracy in most trees of temperate or cold climates; in which, owing to the periodical suspension of vegetation, the annual layers are distinctly marked; and commonly, although not always, they may be distinguished in the trees of the torrid zone.

A corresponding number of layers is deposited in the bark also ; and these would indicate the age of the stem with the same accuracy, were they not continually stretched and rendered indistinct by the growth of the stem, and likewise exposed to the destructive action of external agents on the surface.

In old trees the average thickness of the layers being nearly the same in each species, and the rate of increase very uniform, the age of an Exogenous tree may be determined with considerable certainty by the inspection of a mere fragment, the diameter of the stem from which it was taken being also known. A close estimate of the age of a tree may also be made by measuring its circumference at the base, the average rate of increase for that species having been determined by previous observations. In these several ways the ages of numerous very old trees have been estimated; but the determinations, excepting where they are based upon the actual counting of the rings presented by a transverse section of the trunk, should be received with doubt. Professor Lindley* has pointed out some sources of error which tend, in some measure, to shake our confidence in such calculations.

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* *Introduction to Botany.*

De Candolle has collected the principal facts relative to the most ancient trees known, their ages having been computed from such data as the cases respectively afforded; in some instances by actual counting of the layers, and in others by calculation. The following examples are extracted from a table given in his *Physiologie Végétale*, 2, *p*. 1007. The data upon which these numbers are founded are given in detail in that work,* to which the curious reader is referred for more full information upon this subject. It appears that there now exists, or has existed, upon the earth

An Elm aged	335 years,
Ivy	450 „
Larch (*Larix Europæa*)	576 „
Linden (*Tilia macrophylla*)	1076—1147
Orange	630 „
Cedar of Lebanon	800, or thereabouts,
Olive	700, or nearly,
Oak	810—1080—1500
Yew	1214—1458—2880
Boabab (*Adansonia digitata*)	5130 (in the year 1757.)
American Cypress (*Taxodium distichum*)	4000 to about 6000 years.

The famous Boabab trees of Senegal were measured and their ages computed by Adanson. "The name applied to them in their native country means *a thousand years;* and, contrary to what usually happens, it is below the truth. Adanson saw a tree of this kind in the Cape de Verd islands, which had been observed three hundred years before by two English travellers. He found an inscription left by them upon its trunk covered by 300 layers of wood, and thus was enabled to judge of the average rate of increase." The height of these trees is very small compared with their diameter: with a circumference of from 60 to 90 feet, they attain the height of only 70 or 80 feet, or about three times their diameter. It is very probable that these huge trunks, like those of the famous Cedars of Lebanon, and Chestnut of Mount Etna, are formed by the union of several stems, in which case their computed age is much too high.

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* Also in *Notice sur la longévité des arbres*, in *Bibliothèque Universelle*, May, 1831, by the same author.

The age of the Cypress-trees given in the table was calculated by De Candolle from an account of two Mexican individuals of extraordinary size; but the data upon which the computation is founded are so imperfect that very little reliance can be placed upon the result.

The most aged as well as the largest trees within the limits of the United States are, without doubt, the American Plane-tree (*Platanus occidentalis*) in the Northern and Western, and the Cypress (*Taxodium distichum* of Richard) in the Southern States. The aged trunks of the former are always found decayed in the centre, so that their age cannot be ascertained by counting the layers.

Instances of extreme longevity in the vegetable kingdom will not so much surprise us when we learn that there is no natural or necessary limit to the duration of Exogenous trees; or, in other words, that they never die of old age, as do animals, but are always destroyed by external agency.

II. *The Endogenous Structure.*

40. The essential peculiarities of the Endogenous structure were first clearly pointed out by Desfontaines in a dissertation on the structure of Monocotyledonous (175) plants, published in the year 1796, in the first volume of the *Mémoires de l'Institute.*

Arborescent Endogenous plants, being confined to tropical countries, have afforded to few botanists the opportunity of examining them in their native situations; consequently their structure and growth, though apparently more simple than that of Exogenous plants, is less perfectly understood.

A transverse section of an Endogenous trunk presents a very different appearance from that of an Oak or any other Exogenous stem. There is no bark, properly so called; no concentric woody layers; and no central pith; but these parts are confounded with one another. The stem appears to be wholly composed of longitudinal bundles of fibres, traversing, without apparent order, a spongy matter; and the whole is enclosed within a rind which represents the bark. Unlike the bark of Exogenous plants, this rind has neither liber nor woody fibre in its composition, but wholly consists of indurated cellular tissue, and is inseparable from the stem.

The trunk of a Palm (*fig.* 33) is a fine example of this kind of structure. The fibrous bundles, which represent the fibro-vascular system, are disposed in a confused manner throughout the spongy matter which is the cellular system in these plants; but the fibres are much more abundant near the circumference than towards the centre. In the Cane or Rattan (another variety of Endogenous structure) the woody bundles are very uniformly disposed throughout the whole diameter of the stem. The same arrangement exists in the stems of Smilax rotundifolia, or Green-briar, the only Endogenous shrub of the Northern States (*fig* 34.). The stem of Asparagus, of the herbaceous species of Smilax, &c., are constituted upon the same plan;

Fig. 33.

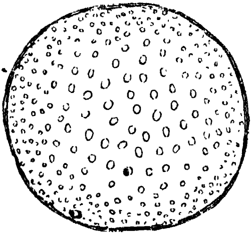
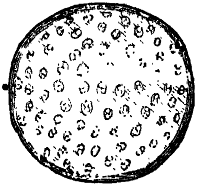


Fig. 34.



but on account of the superabundance of cellular tissue, the structure is not so readily recognised. The slender longitudinal fibres of which the vascular and woody system of Endogenous stems is wholly composed, consist of ducts or spiral vessels and woody fibre. They may be traced as unbroken threads, from the base of the leaves through the whole length of the stem; but they are never arranged so as to form zones or layers as in Exogenous trunks. Endogenous stems possess neither pith as a distinct organ, nor medullary rays, the common cellular tissue of the stem performing the office of both. They increase in diameter by the successive addition of new fibro-vascular bundles within those earlier formed, which are displaced and forced outwardly. From this peculiar mode of growth they derive their name of Endogens, or growers inwardly. In Endogenous stems, consequently, the oldest wood is found next the circumference, and the central portion, having fewer and more recently formed fibro-vascular bundles, is softest. This is a good character for distinguishing such stems from those of Exogenous growth, in which the newly-formed or softest portion is necessarily next the circumference.

There is no provision for the growth of the rind of Endogenous plants, like that of the bark of Exogens. It is, however, capable of distention to a certain extent; but when once become indurated, the stem increases no further in diameter; the horizontal growth of Endogenous plants is therefore necessarily limited. Leaving out of view those rare instances in which the rind remains soft and capable of unlimited distention, Endogenous stems, having grown horizontally with great rapidity to a certain point, do not afterwards increase in diameter at all. The trunks of Palms and most herbaceous Endogens are nearly as large when they first appear as at any subsequent period. Ligatures, or the firm embrace of twining plants, soon destroy the life of Exogenous stems by preventing further increase in diameter; but they do not affect the growth of Endogens. De Candolle has figured a remarkable instance of this kind.* The specimen from which the figure was made is preserved in the Museum of Natural History at Paris; it is a portion of a Palm which, although surrounded and enclosed as in a sheath by a gigantic climbing stem, attained to a great height, its growth being in no way disturbed.

In Endogenous, as in all other Flowering plants, buds are produced at every node; but usually (especially in the Palms and arborescent Endogens) a terminal bud only is developed, the stem being unbranched, and consequently cylindrical. In these instances the lateral buds are latent, and seldom appear unless the terminal one be destroyed. If two terminal buds develop at the same time, a forked stem results. When lateral buds are developed, as in the Green-briar (*Smilax rotundifolia*), (in which case their action is excited by the destruction of the terminal ones during the cold season,) the branches also are cylindrical, being as large at their extremity as at their base. It happens occasionally, however, owing to circumstances which we cannot here explain, that buds are regularly produced in the axils of the leaves. In these cases the stem loses the cylindrical form and becomes conical, like that of an Exogen. Asparagus is an example of this kind.

The life of Endogenous plants, as well as their increase in diameter, is limited by the nature of the rind and external tissue. When the horizontal growth of the stem is once stopped, the rind and the outer tissue harden; the stem, being now incapable of further increase in diameter, can only grow in length; consequently Endogenous stems are generally slender. But the continual deposition of new vascular bundles within the unyielding external portion, finally causes the total solidification of the stem, which is ultimately destroyed as a necessary consequence of its growth. In this sense the life of Endogens may be said to be limited; for unless previously destroyed by external causes, they die from a cause analogous to *death by old age* in animals. The *individual*, however, is seldom destroyed; for while the trunk of a Palm is thus slowly perishing, the great accumulation of sap in the roots causes the development of new shoots from the base of the stem, which continue the life of the individual when the original trunk dies down to the bottom.

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* *Organographie*, tab. IV. See also, for a longitudinal view of the same trunk, *Mirbel, Elém. Phys. Vég.*, *t.* 19, *fig.* 1.

According to this view, the life of Endogenous trees is as truly unlimited as in those of Exogenous growth; for Exogenous trunks frequently die at the centre while they are growing vigorously at the circumference. The Platanus occidentalis, or Plane-tree, furnishes a remarkable and well known illustration of this; the oldest trunks are often wholly decayed, excepting a few of the outer and recently formed layers, which prolong the existence of the individual.

The internal structure of Endogenous stems furnishes no means by which their age may be ascertained. It has been said that in the Palm tribe, the external rings indicating the situation of the leaves coincide in number with the years the individual has lived. Little dependence can be placed upon this circumstance, for in many Palms these rings disappear after a term of years; and besides, it is far from being certain that only a single node results from each year's growth in these plants.

In our observations we have taken the trunks of Palms as the type of Endogenous structure; but those of the Lily, the Solomon's-seal, Smilax, &c., are entirely similar to these, except that their tissue is soft and juicy. To the Endogenous structure belong also a great part of the short subterranean stems, such as the cormi of the Tulip and Colchicum, nearly all bulbs, and many rootstocks.

There is also another variety of Endogenous growth which requires notice, the true structure not being obvious at first sight; viz.: the stems of grasses, which have been stated to be the least endogenous of all Endogenous plants. The peculiarity of these stems is, that they are hollow, except at the nodes, which are very compact rings, closing the stem entirely. They were, however, originally solid, becoming hollow in consequence of rapid growth. In other respects the stems of the woody grasses, such as the Bamboo and the Cane of the Southern and Western States (*Miegia macrosperma*), do not differ from the trunks of Palms. It is said that they sometimes again become solid, by the constant addition of new internal matter.

The principal differences between Exogenous and Endogenous plants, so far as they depend upon the structure of the stem, may be exhibited in this manner:

EXOGENOUS PLANTS.	ENDOGENOUS PLANTS.
Trunk conical, generally branched.	*Trunk* usually simple and cylindrical.
Bark separable from the stem, made up of annual layers; in old trunks cracked or broken into fissures externally.	*Rind* smooth, not made up of concentric layers; inseparable from the stem.
Wood composed of concentric zones, traversed by medullary rays; with a distinct central pith.	*Wood* consists of fibrous and vascular bundles, not arranged in concentric layers; no distinct pith; no medullary rays.
Stem increases in diameter by the successive addition of new woody *layers* externally; consequently the oldest and densest part of the stem is near the centre.	*Stem* increases in diameter by the formation of new woody *bundles* within the old wood; consequently the oldest and densest portion of the stem is at the circumference.
Duration of the trunk indefinite, destroyed only by disease and external causes.	*Duration* and increase of the trunk confined within certain limits; life terminable from the solidification of its tissue.
Root conical, destitute of pith and spiral vessels.	*Root* cylindrical, of the same structure as the stem; sometimes furnished with spiral vessels.
Native, as trees, in all climates.	*Native*, as trees, only in hot climates.

3. Of the Growth of Stems.

41. The stem, which exists in a rudimentary state in the seed, is developed and attains its full size by a double growth, *i. e.* in length and in diameter. When a young plant grows from a seed, or a branch from a bud, the stem in the first place lengthens without any marked increase in diameter. The only tissues which are produced in this upward growth, are the cellular system (34) of the bark and body of the stem, and the medullary sheath with its spiral vessels. The other elements of the stem are afterwards added, and contribute to its increase in diameter.

The stem elongates, not by its extremity only, but throughout its whole length, as is proved by marking at equal and known distances a growing stem The same fact may be observed by noticing the distance between the nodes, or, which amounts to the same thing, of the leaves, of a stem or branch. At first the nodes are closely approximated, and the leaves consequently nearly touch each other; the elongation of the internodes commences with the lowermost and terminates with the uppermost. When the full growth for the season is attained, the leaves, although considerably separated, are equidistant as before. But if the growth of each internode be carefully noticed, we shall observe that its increase in length is principally owing to the elongation of the lower half. The growth of a young shoot proceeds in this manner, without interruption, until it has attained its full length for the season; it afterwards undergoes no further elongation, but its future growth depends upon the production of a bud upon its summit, which develops in the same manner as the original stem; this again produces buds, which are in their turn developed, and thus the stem increases in length from year to year. This process is essentially the same both in Exogenous and Endogenous plants. It usually happens that some of the buds with which the stem is furnished at every node also grow and produce branches, the development and growth of which is precisely similar to the stem from which they originate.

42. Increase in diameter is the combined result of two distinct kinds of growth, viz.: 1st, the development of the cellular system, which grows horizontally as well as upwardly; and 2d, the production of woody and vascular tissue, which grows in a longitudinal direction only. The horizontal expansion of the cellular system is simultaneous with its growth in an upward direction; so that shoots may increase in diameter to a certain extent, at the same time that they grow in length. Plants destitute of a woody system increase in diameter as well as in all other directions from this cause alone; but in all Vascular plants, lateral growth is the result both of the production of cellular tissue, and the deposition of woody fibre and vessels.

When the elongation of the young stem is nearly complete, the formation of wood commences, and its deposition, either in bundles or layers, continues during the growing season; to this cause the increase in diameter is principally attributable.

Concerning the origin of wood, however, and the manner in which its deposition is brought about, there has been a great diversity of opinion among botanists. In the investigation of the subject it became necessary to make repeated observations upon the stems of trees and shrubs, in which a large quantity of woody tissue is deposited from year to year. By far the greater part of the observations hitherto undertaken in view of this subject have been made upon Exogenous trees; to this class, therefore, our attention will be principally directed. But it should be premised, that no theory of the formation of wood is tenable which does not explain the growth of Endogenous as well as of Exogenous plants. The origin of wood is presumed to be the same in both classes, its particular mode of arrangement varying with the diversity of structure.

The plan of this work will not permit us to notice, except in the briefest manner, the opinions of the old botanists upon this subject. Linnæus believed the wood to be produced by the pith, and that new layers were added internally to the old wood; an opinion which has been adopted by no succeeding physiologist.

Hales supposed the new layers to be a deposition from the alburnum of the preceding year. To this view the opinions of Malpighi and Grew, the fathers of vegetable physiology, were diametrically opposed. They maintained that the liber produced each year a net-work of vessels, primarily intended for the transmission of the sap, which finally became too firm and rigid for the performance of this office, and, adhering to the alburnum, formed a new layer of wood. Du Hamel made some ingenious experiments in illustration of this subject. He carefully introduced plates of tinfoil between the bark and wood of growing trees; after some years, on cutting them across, the new layers of wood were found to have been deposited on the outside of the tinfoil. These observations led him to adopt, in great part, the theory of Malpighi, only that he supposed the inner layer of the liber to be itself every year changed directly into wood. His experiments conclusively prove that the new layer is not a production of the surface of the old wood; but they do not demonstrate, as he supposed, that it originates from the bark.

Mirbel originally adopted the theory of Du Hamel with some modifications of his own. He supposed the cambium, (a mucilaginous fluid which is found between the wood and bark at some seasons) to be the real source of vegetable growth: that each annual layer of the liber is composed of woody fibre and cellular tissue intermixed, the woody fibre being most abundant however on the side next the wood: that the liber, being nourished by the cambium, and having attained a considerable thickness, separates throughout its whole extent into two portions; the outer adhering to the bark forming the new layer of liber, while the inner and more fibrous portion uniting with the wood constitutes the new layer of that substance. This theory Mirbel afterwards abandoned, having satisfied himself that the liber never becomes wood. He substituted a different view,* in which the cambium, as before, has an important place. This substance, he contends, is not a simple fluid, but an organized tissue in the incipient state, which is deposited in spring and autumn, and forms a layer between the wood and bark. This delicate newly formed tissue soon acquires a firmer consistence, and at length divides into two layers, one of which is added to the wood, the other to the bark.

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* *Bulletin de la Société Philomathique*, 1816, p. 107.

An important objection may be brought against this and all preceding theories upon this subject, viz.: that they do not explain the formation of wood in Endogenous plants, which have neither cambium nor liber, and in which the wood is produced in the interior of the stem, so that the bark can have no direct agency in its formation.

Mr. Knight, about the same time, engaged in a series of experiments to determine the origin and nature of the bark and wood, which greatly elucidated the subject, and reduced the inquiry within narrower limits. He observed that a growing branch will perish when its leaves are destroyed; "if the leaves of the upper portion of the branch only are stripped off, the branch will die down to the place where the leaves are left, and below that will flourish." He removed a ring of bark from above and below a portion of the stem which was furnished with a single leaf, and observed that a perceptible increase took place in the wood below the leaf, but none above that point. Mr. Knight justly inferred from these observations, that the leaves exert an important influence over the production of wood. It is also proved by repeated observations, that when a growing branch is girdled by the removal of a narrow ring of bark, the branch will increase sensibly in diameter down to this ring, but will not at all increase between the ring and the leaf next below it. If the removed portion of bark be narrow, the vacant space soon closes by the deposition of new matter to the upper edge of the wound, and afterwards the inferior portion of the limb increases in diameter as if nothing had happened to interrupt its growth. If a ligature be tightly applied around a growing stem, the portion above the ligature swells, that below does not. The pressure of twining plants not unfrequently produces strange distortions in growing Exogenous stems, and unless the ligatures are removed such stems are finally killed. From these and similar facts we may safely infer, that the matter of which wood is formed, originates in the leaves and is sent downwards.

It is well established, moreover, that the diameter of a stem depends very much upon the number of leaf-buds it bears; the larger the number of these developed upon a branch or stem, the greater will be its diameter, and, the more rapid its increase. Wood is formed also most abundantly upon that side of the stem which develops the greatest number of leaf-buds.

These facts being admitted, the theories of the production of wood are reduced to two, between which botanists are at present pretty equally divided. One view is, "that wood is organized matter sent directly downwards from the leaves and buds;" the other, that wood is produced from organized matter elaborated in the leaves, descending by a returning circulation into the liber and alburnum, and thence deposited between the two in the form of new wood and bark. According to the first view the cambium is elaborated sap transmitted through the liber, serving to nourish the descending fibres. According to the second theory, which, it will be observed, is that of Mirbel with some modifications, the cambium is itself an organizable substance, which either originates or results in new wood. This theory is advocated by many botanists of the highest order, among whom are Mirbel, Desfontaines, and De Candolle, and the principal circumstances relating to the growth of Exogenous plants may be well explained by it. The most serious objection to it, as a universal theory, has been already adverted to, viz.: that it does not account for the growth of Endogenous plants. The essential cause of the production of wood is undoubtedly the same in all Vascular plants; cambium only exists in one division of Vascular plants, and therefore cannot be justly assumed as the essential cause of the formation of wood.

The former theory, viz.: that woody fibre descends directly from the buds and bases of the leaves, has in this respect an important advantage, inasmuch as it explains, with equal readiness, the production of the fibro-vascular system both in Exogenous and Endogenous plants. It was advanced by Du Petit-Thouars, an ingenious vegetable physiologist, who possessed unusually favorable opportunities for investigating the growth of the arborescent Endogens during a residence of several years in the Isle of France.

"The attention of Du Petit-Thouars appears to have been first especially called to the real origin of wood by having remarked, in the Isle of France, that the branches which are emitted by the truncheons of Dracæna (with which hedges are formed in that colony) root between the rind and the old wood, forming rays of which the axis of the new shoot is the centre. These rays surround the old stem; the lower ones at once elongate greatly towards the earth, and the upper ones gradually acquire the same direction; so that at last, as they become disentangled from each other, the whole of them pass downwards to the soil. Reflecting upon this curious fact, and upon a multitude of others which I have no space to detail, he arrived at the conclusion that it is not merely in the property of increasing the species that buds agree with seeds, but that they emit roots in like manner; and that the wood and liber are both formed by the downward descent of bud-roots, at first nourished by the moisture of the cambium, and finally imbedded in the cellular tissue which is the result of the organization of that secretion. That first tendency of the embryo, when it has disengaged itself from the seed, to send roots downwards and a stem and leaves upwards, and to form buds in the axils of the latter, is in like manner possessed by the buds themselves; so that plants increase in size by the endless repetition of the same phenomenon.

"Hence a plant is formed of multitudes of buds or fixed embryos, each of which has an independent life and action; by its elongation upwards forming new branches and continuing itself, and by its elongation downwards forming wood and bark; which is, therefore, in Du Petit-Thouars' opinion, a mass of roots."

This original and highly ingenious theory at first met with few supporters. Of late it has excited considerable attention, and, with some modifications, has been adopted by several eminent botanists. It is very ably defended by Prof. Lindley in his Introduction to Botany, (from which the above extract has been taken,) and in his other botanical works. To obtain correct views on this subject, it should be borne in mind that only one of the two systems which compose the stem is supposed, according to this view, to originate at the leaf-buds; *i. e.* the fibro-vascular system, which is capable of longitudinal growth only. Its elongation upwards produces the medullary sheath, the earliest-formed portion of that system either in a branch or in the original stem as it develops from the seed. Its downward extension produces wood; a portion of the descending fibres also attaching themselves to the liber, give the bark a somewhat fibrous structure. Meanwhile the cellular system continues its horizontal growth, forming the matrix in which the fibro-vascular portion is imbedded. These two components of the stem, the one growing vertically and the other horizontally, cross each other at right angles; and the trunk has been quaintly but not inaptly compared to a piece of cloth; the cellular system representing the woof, and the fibro-vascular system the warp. The descending juices of the plant and the cambium doubtless furnish the material for the lateral extension of the cellular system as well as nourishment for the descending fibres.

By assuming this view Prof. Lindley has been able to obviate nearly all the objections that have been brought against the theory of Du Petit-Thouars, as applicable to the growth of Exogenous plants.

In Endogenous stems the bundles which compose their fibro-vascular system may be distinctly traced quite into the leaves, so as to render this theory even more plausible in these than in the Exogenous division. Here the new fibrous bundles cannot be said to be a deposition from the bark, since they are formed in the centre of the trunk. Moreover, in some Exogenous stems the wood does not form regular circles all around the trunk; sometimes it is nearly all deposited upon one side, or along certain lines. In some instances the woody fibres are curiously interlaced, crossing each other diagonally so as to form a kind of lozenge-work. These circumstances are unaccounted for by the theory of Mirbel and De Candolle, but are readily explained by that of Du Petit-Thouars and Lindley.

Several objections have, however, been brought against the latter theory which have not been satisfactorily answered, as in the following case.

If we graft a ring of bark of the Plum-tree, destitute of buds, upon the trunk of an Almond, the new bark will adhere to the old wood, and the tree will grow as if nothing had happened. After a year or two, if we cut off the trunk at this place, we find under the ring of Plum-tree bark a quantity of wood, which has all the characters of that of the Plum-tree and not of the Almond. Now, according to the theory of Du Petit-Thouars, this wood is the produce of the leaves and buds of the Almond-tree, and ought, if the theory be true, to be the same as the wood above and below it, which clearly it is not. The only plausible answer in this case is, that the wood is really that of the Almond throughout so far as the fibro vascular system is concerned, but that its color, grain, &c. are derived from the medullary rays which are furnished by the bark of the Plum-tree. This answer, however, rests upon a gratuitous assumption, and is not quite so convincing as could be wished.

We adduce one other instance which Mirbel has brought to bear against this theory with much ingenuity. We translate from the article *Couches Ligneuses* and *Couches Corticales* in the *Cours d'Agriculture*, published during the past summer. "Suppose," says Mirbel, "that a scion of Robinia inermis had been grafted for a long time, say 30 years, upon a young stem of Robinia Pseudacacia, or common Locust, cut off six or eight feet from the ground. According to the system (of Du Petit-Thouars), what has taken place during the 30 years which have elapsed since the grafting? The buds of Robinia inermis have each year sent out roots, which, under the form of a layer of wood, have insinuated themselves between the wood and the bark of the Robinia Pseudacacia, extending quite to the earth. Thus the trunk has successively acquired 30 layers of the wood of Robinia inermis, since they have been produced by the buds of that species; and these layers one after the other are divided in the soil, and spread in the form of roots, which are also those of Robinia inermis. Now if we cause these roots to develop buds, and thus form new stems, we should, according to this theory, obtain stems of Robinia inermis. But in fact, these roots give rise to stems of Robinia Pseudacacia; and, consequently, their specific organization is that which is proper to the latter species. As these roots are nothing more than prolongations of the vertical and woody layers of the trunk, the latter must also belong to Robinia Pseudacacia. It is here evident that neither the roots of the tree nor the wood and bark of the trunk originated from the buds of Robinia inermis."

However plausible, therefore, the theory of Du Petit-Thouars may be, it cannot yet be considered as established, but is liable to several strong and, up to this time, unanswered objections; nor, while there is essential agreement as to the manner in which the stem grows, is it of much practical importance to ascertain the exact origin of the woody fibres.

SECT. IV. *Of Leaf-Buds.*

42. A BUD is a protuberance formed by a new shoot or branch at the commencement of its growth. They exist, or are capable of existing, in the axils * of all leaves, and generally appear in no other part of

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* The angle formed by the base of the leaf, at its upper side, and the stem, is its *axil.*

the plant; consequently their *normal* situation is at the nodes. The term *bud* is employed with some ambiguity in the works of Linnæus. Sometimes it is used for the rudiment of the young shoot with its envelopes, and sometimes for these envelopes only. It is here uniformly employed in the first sense.

The principal facts concerning the nature of buds, and their office in connection with the increase of the stem, have in part been anticipated in the preceding section.

In Exogenous plants the buds originate in the pith and grow towards the surface. In their progress they carry along a portion of the medullary sheath, and when they reach the bark acquire a coating of cortical integument. Thus their structure is similar to that of the stem from which they arise; *i. e.* they have pith in the centre, surrounded by a medullary sheath, and over all a coating of cellular integument. When a single bud stands on the summit of a stem or branch, it is said to be *terminal;* when several appear along its sides in the axils of the leaves, they are said to be *lateral* or *axillary.**

The origin of buds in Endogenous stems has not been well observed; no doubt they arise from the spongy cellular matter which represents the pith in these plants.

When buds make their appearance externally, they either shoot at once into a branch, or remain for some time dormant: in the latter case they are usually provided with a covering of scales; in the former, they are naked or destitute of scaly coverings. All herbaceous plants, and most trees and shrubs of hot climates, have naked buds. Scaly buds exist in nearly all the trees and shrubs of this country; they appear at the time when vegetation is in its greatest vigor; *i. e.* during the summer, and remaining stationary during the winter, are developed in the ensuing spring.

43. The coverings of buds consist of abortive scale-

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* A terminal bud, strictly considered, being only the growing extremity of the old branch, originating in the axil, it may be said that all buds are axillary.

like leaves, lying compactly over each other in several rows. Their nature is evident from the gradual transition into true leaves which is seen in the full-grown buds of several trees, especially in the Horse-chestnut tribe. The outermost scales of the buds of the Horse-chestnut, or the Buck-eye (*Æsculus Pavia*), are short, hard, and dry; those of the next row are more delicate; the inner series are still more membranous and slender, some of these bear at their summits the rudiments of leaflets and are intermediate between scales and true leaves. Scaly buds have received several names according to the nature of their teguments; thus they are said to be

1. *Foliaceous*, when the scales consist of the laminæ (52) of leaves in an imperfectly-formed state;

2. *Petiolaceous*, when they are formed of the dilated base of petioles (52), as in the Ash, and the Horse-chestnut just referred to;

3. *Stipulaceous*, when they consist of stipules (62) only. Of such buds two kinds may be distinguished; 1st. in which the scales are stipules rolled together, enveloping the bud in the ordinary manner, as in the Beech, the Birch, and all Amentaceæ; and 2d. where each leaf is enclosed within a stipule, as in the Tulip-tree (*Liriodendron tulipifera*) and all other Magnoliaceæ. The latter are at once distinguishable by their remarkably elongated form. Lastly buds are,

4. *Fulcraceous*, when their teguments are composed of petioles and a pair of stipules grown together, as in the Plum-tree and other Rosaceæ; such scales are frequently three-lobed.

Scales evidently serve for the protection of the bud against humidity and sudden changes of temperature. That they may effectually perform this office, the scales closely envelop each other and are sometimes arranged in an imbricated manner. They are often coated with a resinous varnish, which renders them perfectly impermeable to water (*Ex.* Walnut, Horse-chestnut, the Balm-of-Gilead, Poplar, &c.). An additional provision against changes of temperature is not unfrequently afforded by a thick mass of wool or down which surrounds the bud (*Ex.* Horse-chestnut, Willow).

The naked buds of Smilax rotundifolia are surrounded and protected during the winter by the dilated and persistent base of the petiole of the old leaf; this substitute for scales, having fulfilled its use, falls away in the spring.

Some scaly buds are similarly protected during their growth. A very curious instance of this kind may be seen in the American Plane tree (*Platanus occidentalis*). In this tree we seek in vain for the buds in their ordinary situation at the axils of the leaves; they are concealed within the swollen base of the petiole, which dilates into a little cup for the reception of the bud, perfectly enclosing it until the fall of the leaf The same contrivance may be observed in Virgilia lutea, a fine tree growing in the Western States, and also in the common Locust (*Robinia Pseudacacia*).

44 Leaf-buds are of two kinds, the *regular* and the *adventitious*. Regular leaf-buds are produced in the axils of all leaves. Sometimes two or more buds exist in the same axil, as in the Peach-tree, but this is of uncommon occurrence.

The complete development of a bud produces a branch; consequently the mode in which a stem branches depends upon the arrangement of its buds, and the arrangement of the buds is governed by the disposition of the leaves. Thus alternate-leaved (60) stems have alternate branches, and opposite-leaved (60) stems opposite branches. Their symmetry, however, is continually destroyed by the non-development or subsequent destruction of buds, since it seldom happens that all the buds of a stem grow into branches.

We often find three buds upon the summit of the stem of an opposite-leaved plant, viz.: a terminal bud and one in the axil of each leaf. As the terminal bud merely continues the original stem, its growth does not alter the arrangement of the branches. But these three buds seldom grow at the same time. Sometimes the lateral buds are obliterated and the terminal one continues the stem, as in the Horse-chestnut. Sometimes the terminal bud perishes and the lateral ones grow, when the branches become two-forked, as in the Lilac.

Alternate-leaved plants exhibit the same diversity. When both the terminal bud and that of the axil of the uppermost leaf grow at the same time, two-forked branches result. But often the terminal bud alone grows and continues the stem, as in the Peach and the Apple-tree: sometimes the terminal bud perishes and the lateral one continues the stem, as in Tilia, the Apricot, &c

45. When buds make their appearance from any other part than the nodes, they are termed *adventitious*, *irregular*, or *abnormal* buds. These are not of very common occurrence, and the cause of their production is unknown, yet they are continually appearing from the root and on the trunk of some trees, such as the Poplar. Every organ provided with vessels and fibre seems to have the power of producing such buds; in several instances they are found arising from the surface or margin of leaves (*Ex.* Bryophyllum).

46. When the extension of a leaf-bud is checked during its development, it hardens and becomes sharp-pointed, forming a *spine* or *thorn*. Spines, therefore, are imperfectly-formed branches, and are very different from prickles (20); the wild Thorn and the cultivated Hawthorn exhibit all the gradations between spines and branches. Spines, being furnished with rudimentary buds, often disappear in cultivated plants, being changed into true branches (*Ex.* the Pear and the Apple-tree). The spines of the Barberry are transformed leaves.

Turions are the young scaly shoots which arise in the spring from the neck or rhizoma of herbaceous perennial plants; they differ from ordinary leaf buds only in their subterranean origin (*Ex.* the early shoots of Asparagus).

Bulbs are leaf-buds provided with a covering of fleshy or membranous scales, and situated upon the summit of an extremely short subterranean stem; their relation to stems has already been considered (32).

47. Leaf-buds in many respects resemble seeds; both containing a rudimentary plant, or germ, capable of

growth in two opposite directions; and both serve for the reproduction of plants. Buds, however, are the necessary result of the growth of a stem; seeds are only produced by the agency of flowers: buds perpetuate the individual; seeds continue the species.

Buds usually perpetuate the individual by means of runners, offsets (28), bulbs (32), &c. By facilitating these natural operations we are enabled to multiply favorite varieties or individuals to any extent; by these means alone can varieties be perpetuated, for seeds continue the species only.

Cultivators employ several methods for the increase of individuals, viz.: 1st by *division;* cuttings of stems furnished with vigorous buds, being made to take root and grow by themselves. The Willow, Vine, and all stems that readily form adventitious roots, may be propagated in this manner. 2d. by *budding,* which consists in transferring the buds of a plant to the stem of a similar or nearly-related species. The bud, with a piece of the bark attached, is removed from the parent plant and carefully fitted to the wood of the stock, so that it freely receives the ascending sap. The bud soon adheres firmly, and grows like the original buds of the tree. 3d. by *grafting,* which is performed, as is well known, by several modes. It essentially consists in causing a branch, furnished with one or more active buds, to grow upon the stem of another plant. We only succeed in this, when the scion and the stock belong to the same or nearly-allied species.

48. The manner in which the young leaves are folded and packed together in the bud is called the *vernation* or *præfoliation.* Their arrangement is highly curious, and is perfectly uniform in all the buds of a given species. The principal forms of vernation are:

1st. The *appressed;* when the leaves are applied to each other face to face without being folded or rolled together (*fig.* 35, *a.*).

2d. The *opposite* (or *imbricate*); when the leaves are placed in pairs at right-angles to each other and half-folded, so that the outer pairs enclose the inner ones, as in the Lilac (*fig.* 35, *b.*).

3d. The *equitant;* when alternate leaves are folded lengthwise, and overlap each other longitudinally at the margins. *Ex.* Iris (*fig.* 35, *c.*).

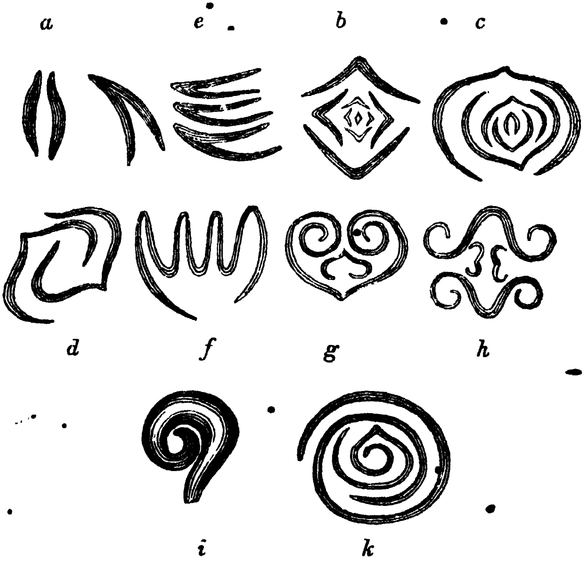
4th. The *half-equitant,* (*obvolute Lindl.*); when one of the margins of each leaf is exterior and the other interior. *Ex.* Sage (*fig.* 35, *d.*).

5th. The *conduplicate;* when the leaves are folded inwardly upon themselves, and placed side by side, as in the Rose (*fig.* 35, *e.*).

6th. The *plicate,* or *plaited;* when they are folded several times like the plaits of a closed fan. *Ex.* the Vine (*fig.* 35, *f.*).

7th. The *involute;* when the edges of the leaves are spirally rolled inwards; as in the Violet (*fig.* 35, *g.*).

Fig. 35.



8th. The *revolute;* when the edges are rolled outwards. *Ex.* the Rosemary (*fig.* 35, *h.*).

9th. The *convolute;* when the leaf is rolled up from one of its edges, as in the common cultivated Cherry (*fig*. 35, *i*.).

10th. The *circinate;* when it is rolled spirally from the apex downwards, as in the Sundew (*Drosera*) (*fig*. 35, *k*.).

SECT. V. *Of Leaves.*

49. The foliage consists of numerous appendages of the stem and branches, of an expanded form and infinitely varied outline, bearing the name of *leaves*. Leaves are the principal organs of vegetable nutrition: they receive the ascending sap, the superfluous fluid portion is here dissipated by evaporation, and the remainder under the influence of light and air undergoes certain important changes. This process, which is in part analogous to the respiration of animals, will be the subject of future consideration.

All Flowering plants are provided with leaves at some period of their existence; and when they disappear, as in the Prickly-pear, the green cellular integument of the stem assuming a more leaf-like structure takes their place. There are a few plants destitute of leaves or furnished with scales only, in which the surface of the stem does not become green, being therefore incapable of performing the functions of leaves. Such plants, however, are mostly, perhaps always, *parasitic;* that is, their roots affix themselves to the stems of other leafy vegetables (*Ex*. the Dodder), or to their roots (*Ex*. Monotropa, Orobanche, and Epiphegus or Beech-drops), and drawing their nourishment from the juices of these plants, they have no need of leaves.

The rudiments of leaves may be seen in the bud at an early period, in the form of minute scales; they grow as the bud enlarges and attain their full size after its development into a branch. At first the leaf is continuous with the stem, but after some time a *joint* or *articulation* is formed with the stem. When the joint is perfected, the leaf falls off.

Leaves are so placed upon the stem that one surface is presented to the sky and the other to the earth. If their direction be interfered with, or altered by the drooping of the branches, as in the Weeping Willow, they soon return to their original position by twisting their footstalks. The two surfaces of the leaf are very seldom exactly alike; the upper surface is usually smoother and has a deeper green color.

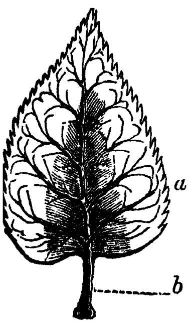
50. The structure of leaves is more complex than is generally supposed; their organization is highly curious and admirably adapted to the purposes for which they were created. Being thin and expanded portions of the stem, they are, like that organ, composed of two systems, viz.: a cellular system, which is an expansion of the cellular integument; and a fibro-vascular system, which arises from the medullary sheath and is prolonged into the cellular expansion, throughout which it branches, producing what is appropriately termed the skeleton or frame-work of the leaf. The whole is invested by a cuticle, a continuation of that which covers the stem.

A good idea of the structure of a leaf will be obtained by conceiving it to arise from the protrusion of a portion of the medullary sheath (or in Endogens of one or more vascular bundles) into the bark; which, at this early period, wholly consists of cellular integument invested by the cuticle. The continued extension of the fibrous portion, pushes outwardly the fold of bark in which it had been insinuated; at length the fibres diverge from each other in a horizontal direction, and carrying the cellular system with them produce the flat and dilated figure of the leaf. The leaf, therefore, if our supposition be accurate, consists of an upper and lower stratum of cellular integument, and a double frame-work of fibres. The two strata, however, are usually intimately and inseparably united; but when the cellular portion is destroyed by long-continued maceration in water, (as may sometimes be observed in leaves which have lain during the winter in a ditch,) the frame-work may often be separated into two layers. In some curious East Indian leaves, it is said, the connection is so slight "that they open with a little violence like the leg of a silk stocking, so that the hand may be thrust between their upper and lower surfaces."

The frame-work, like the medullary sheath from which it proceeds, consists of, numerous spiral vessels surrounded on every side by woody fibre. At the base of the leaf these vessels all lie side by side in a bundle Within the leaf they divide into several smaller bundles, which ramify in like manner, and the division proceeds until each vessel is separated from those which accompany it, and is wholly surrounded by cellular tissue; then, turning back upon themselves they converge precisely in the same order, forming larger and fewer bundles until they again meet in a single bundle at the base of the leaf. It is commonly thought that the upper layer of vessels conducts the ascending sap into the leaf, while the lower one returns the elaborated sap into the bark.* This opinion is very probable, but is not founded upon positive evidence.

The bundles of vessels which compose the frame-work of the leaf are called *veins*, and sometimes *ribs*. They have also been called *nerves* or *nervures*, which are decidedly improper appellations There is commonly a principal vein, apparently a continuation of the leaf-stalk, which passes along the centre of the leaf, from one end to the other, sending off branches in its course; this is termed the *midrib* (*fig*. 36.). The branches that arise directly from the midrib are called *primary* veins; the branches of the latter are *secondary* veins; and the slender ramifications are called *veinlets*.

Fig. 36.



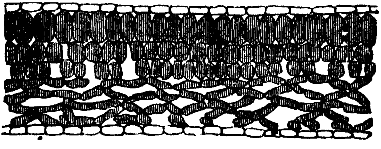
51. The cellular system of the leaf, which De Candolle terms the *mesophylle*, is usually called the *parenchyma*. It accompanies the fibro-vascular system throughout, filling up the interstices of its ramifications. Its cellules contain a green substance (5, 81), upon which the color of leaves depends. When the

parenchyma is excessively abundant,* the leaves become *succulent*, as in the Ice-plant. When, on the contrary, it is sparing in quantity, the leaves are thin and *membranaceous*. In the abortive leaves which form the covering of buds, there is often an apparent suppression of parenchyma, and even of veins.

The cuticle (15), which encloses the parenchyma and adheres to it more or less firmly, is a colorless and transparent membrane, composed of one or several layers of cellules, either flattened together or filled with air. It is furnished with breathing-pores, which are commonly most abundant on the lower surface of the leaf. In erect leaves, like those of the Iris, they are equally numerous on both surfaces. The structure of the cuticle, as well as the arrangement of the breathing-pores, is perfectly uniform in all individuals of the same species.

The parenchyma of the leaf exhibits to the naked eye the appearance of green pulp, destitute of regular arrangement; but "if thin slices be viewed with a high magnifying power, it will be seen that nothing can be more perfect than the plan upon which the whole structure is contrived, and that, instead of disorder, the most wise order pervades the whole." The stratum which belongs to the upper surface is usually composed of three or four layers of oblong cellules, very compactly arranged with their longest diameter perpendicular to the surface. Those of which the lower portion of the leaf consists are also oblong, but are placed parallel with the cuticle, and are very loosely arranged, forming a kind of net-work and leaving numerous empty spaces, which communicate with the

Fig 37.



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* "Any part in which there is an unusual degree of cellular development, is said to be in a state of *anamorphosis*."—*Lindley, Outlines of Botany*, Art. 48.

breathing-pores, and of course contain air. This is the usual structure of the leaves of trees. *Ex.* the Apple-tree (*fig.* 37.). The deeper tint which the upper surface of most leaves presents is due to the greater compactness of its cellules. This structure is well adapted to restrain the excessive evaporation which would otherwise take place from the upper surface, on account of its direct exposure to the sun. At the same time it is fitted for the performance of a kind of vegetable digestion (74). Evaporation (75) and respiration (76, 77) are, it would seem, principally carried on by the parenchyma of the lower surface.

There are some plants whose leaves float upon the water and only expose their upper surface to the air (*Ex.* the Water-lily). In these cases evaporation and respiration cannot go on from the lower surface, and accordingly the structure of the leaf is reversed, the breathing-pores and the cavernous parenchyma belong to the upper surface, and the lower portion is compact. In leaves which are habitually under water the cuticle does not exist, and the air-cavities are just sufficiently numerous to render them buoyant.

In leaves like those of the Iris, where both surfaces are equally exposed to the light, the parenchyma is wholly compact, except at the breathing-pores, where air-cavities exist.

52. A leaf ordinarily consists of two parts, viz.: the expanded portion, to which the name is usually applied, and its little stalk or support. The former, when separately spoken of, is called the *limb* or *lamina* (*fig.* 36, *a.*); the latter is termed the *petiole*, and sometimes the *foot-stalk* or *leaf-stalk* (*fig.* 30, *b.*).

When leaves are provided with a foot-stalk, they are said to be *petioled:* when, as often happens, the frame-work spreads immediately on leaving the stem, there is no foot-stalk and the leaf is said to be *sessile*.

The angle which the leaf makes with the stem is called its *axilla* or *axil*. The end of the lamina next the stem or petiole is termed its *base;* the opposite extremity is the *apex;* and the line which represents its outline, the *margin* or *circumscription*.

A leaf is either simple or compound. It is *simple* when the lamina consists of a single piece, whatever may be the degree or manner in which it is cleft or divided. Thus, the examples given under *fig.* 45 and *fig.* 46 all represent simple leaves, notwithstanding the great diversity of outline which they exhibit. Where the lamina is deeply lobed or cleft, as in several of these examples, the leaf is said to be *divided*; the divisions in such cases being technically called *segments*. These forms, however, must not be confounded with compound leaves, as they universally have been until within a comparatively recent period.

A *compound* leaf (*fig.* 49, *b*) consists of several parts or secondary laminæ, each of which is articulated with the common petiole, in the same manner as the latter is connected with the stem. The separate portions of a compound leaf are distinguished as *folioles* or *leaflets;* and these again may exhibit every diversity of outline observable in simple leaves. It is necessary that this view of the distinction between simple and compound leaves should constantly be borne in mind, since a genus with simple leaves scarcely if ever exhibits an instance of a truly compound leaf, thus naturally confirming this view of the case.

53. The shape of the *lamina* of the leaf, which is almost infinitely varied, furnishes excellent characters for distinguishing species from each other. Although its various forms have been described in all elementary works from the time of Linnæus to the present, no attempt had been made to explain the cause of these diversities until the subject was investigated by De Candolle.* He found that the shape and outline of leaves depend almost entirely upon the arrangement of their fibro-vascular portion or frame-work. The distribution of veins in the leaf had been very slightly noticed by the old botanists. Linnæus distinguished but two modifications of venation, viz.: 1st. where the veins diverge from the midrib, and branch over the leaf,—this he called a *veined* leaf; and 2d. where the veins all

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* *Flore Française*, and *Organographie Végétale*, I. p. 289.

spring from the base of the leaf, and run to its apex,—a leaf with this arrangement of its veins was said to be *nerved.* Here the same organs receive in one case the name of veins, and in another that of nerves.

De Candolle contrived a very ingenious classification of leaves according to the distribution of their veins: a more recent and somewhat simpler arrangement has been given by Prof. Lindley. We adopt the primary divisions of the latter author.

There are three principal modes in the distribution of veins, to which all leaves may be referred, viz.: the Fork-veined, the Reticulated or Netted-veined, and the Parallel-veined.

1st. *Fork-veined* leaves are those in which the veins, arising from the midrib, are once or twice forked (*fig.* 38.), the branches passing directly to the margin, without uniting with each other, or forming a net-work. This kind of veining is peculiar to the Ferns, a tribe of Flowerless plants, but is not universal in these, several species having beautifully reticulated veins. In Exogenous plants a near approach to this kind of veining is seen in the leaves of Clover.

Fig. 38.

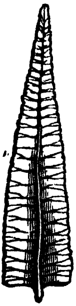
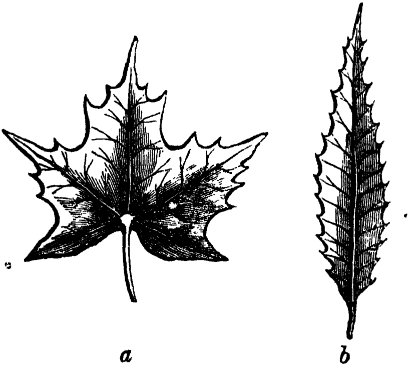


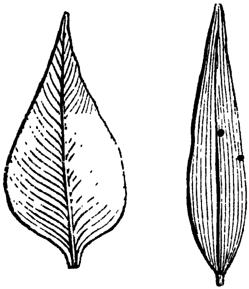
Fig. 39.



2d. ***Reticulated*** **or** ***Netted-veined*** **leaves (feuilles angulinerves,** ***De Candolle*****) result from the continual** branching of the veins, the ramifications of which, uniting with each other, form a net-work over the whole surface of the leaf (*fig.* 36, and 39, *a*, *b*.). These are the *veined* leaves of Linnæus. They are characteristic, with few exceptions, of Exogenous plants; thus furnishing the student, in most cases, with the readiest means of at once distinguishing a plant of that division.

3d. ***Parallel-veined*** leaves are those the veins of which proceed, without branching, from their origin at the base or midrib, to their termination at the apex or margin of the leaf (*fig.* 40, *a*, *b*.). The veins in such leaves are connected by minute veinlets, which pass at right angles from one to the other. These are the *nerved* leaves of Linnæan botanists. The leaves of all Endogenous plants, a few cases excepted, are parallel-veined. Thus the two great divisions of Flowering plants may be distinguished by the veining of their leaves.

Fig. 40.



We return to the consideration of reticulated leaves, of which two modifications are distinguished, viz.: the feather-veined and the radiated.

1st. The ***Feather-veined*** form (feuilles penninerves, *De Candolle*) results whenever there is a midrib, from which the primary veins diverge like the plume of a feather. The leaves of the Chestnut (*fig.* 39, *a*.), and all trees of the same tribe, are good examples of this kind.

The shape of feather-veined leaves chiefly depends on the direction and relative length of the primary veins. In the Chestnut they pass in a straight line to the margin of the leaf, and are directed forwards so as to make an acute angle with the midrib; such leaves are usually considerably elongated.

When the primary veins are short and all of the same length, the leaf assumes a *linear* shape (*fig.* 41, *a*.): if the middle veins are longer than those of the base or apex, the leaf becomes *oval* or *oblong* (*fig.* 41, *b.*). If the veins next the base are longest, and especially if they curve forwards towards their extremities, the outline of the leaf will be *ovate* (*fig.* 41, *c.*); and if on the other hand, the veins beyond the middle are longest, it will be *obovate* (*fig.* 41, *d.*).

Fig. 41.

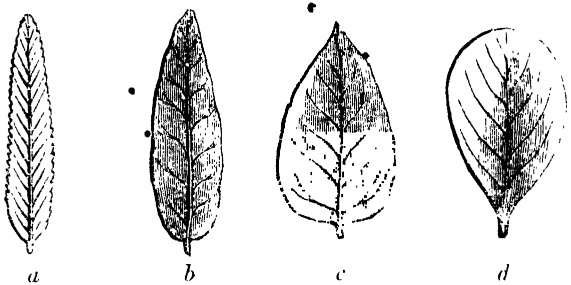
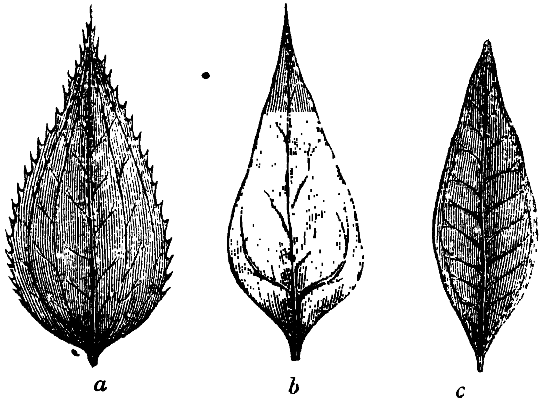


Fig. 42.

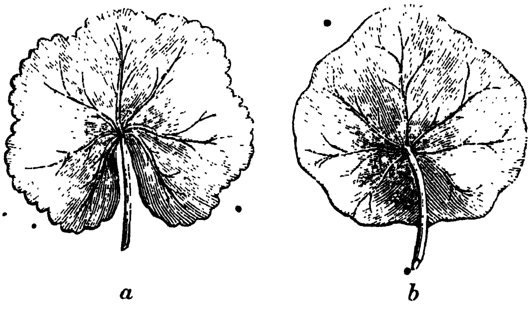


Sometimes the veins that originate next the base of the leaf are nearly as large as the midrib itself (*fig.* 42, *b.*); these prominent veins, which also pass towards the apex, giving off branches in their course, are called *ribs*; and such leaves are said to be three, five, or seven ribbed, the midrib being counted with the others. By these deviations a gradual passage into the radiated form is effected. When the veins diverge from or near the base and converge again to the apex (*Ex.* Rhexia, *fig.* 42, *a.*), they greatly resemble parallel-veined leaves, from which they are distinguished by the netting of their secondary veins.

Sometimes the veinlets are confluent along the margin, forming two lateral ribs (*fig.* 42, *c.*), an arrangement which is well-marked in the Myrtle tribe, and is occasionally observed in other families Such leaves are said to be *falsely ribbed.*

2d, In the *Radiated* form of reticulated leaves, the petiole divides at its extremity into several branches, which proceed, usually in a radiate manner, from the base of the leaf to its circumference. Such leaves have no midrib, and no true apex unless the principal veins converge as in *fig.* 42, *a.* The leaves of the Maple (*fig.* 39, *b.*) and of the Mallow (*fig.* 43, *a.*) belong to this form. These are called *palminerved* leaves by De Candolle, who distinguishes as a separate mode of veining, those cases in which the petiole seems to be placed, not at the base, but at the lower surface of

Fig. 43.



the leaf, the veins diverging in every direction from its extremity like the radii of a circle. This mode of veining has been termed *peltinerved*, and such leaves are called *peltate* or *shield-form*. Of this, the Tropæolum or garden Nasturtium (*fig.* 43, *b.*) is a familiar example. Here the veining is obviously a slight modification of the radiated form. If the contiguous edges of the base of a leaf like that of the Mallow (*fig.* 43, *a.*) should happen to grow together, a peltate leaf would result.

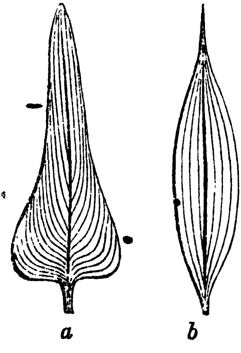
Orbicular, roundish, and ovate forms are usually assumed by radiated-veined leaves; obovate, lanceolate, or linear ones are, for obvious reasons, quite uncommon.

It should be mentioned that the secondary veins of radiated leaves are always disposed according to the feather-veined method; so that we may assume the latter as the type of the venation in Exogenous plants, and conceive a radiated leaf to result from the union of several feather-veined ones.

There are also two kinds of parallel-veined leaves, viz.: the curve-veined and the straight-veined form.

In the *curve-veined* form (*fig.* 40, *a.*) the veins pass in a curved manner from the midrib to the margin. Our native plants exhibit few well-marked examples of this kind, but they abound in tropical vegetation. This form, by a gradual transition, through such leaves as that of Pontederia cordata (*fig.* 44, *a.*), passes into the *straight-veined* kind. In the latter the veins all arise at or near the base of the leaf, and proceed to the apex, nearly parallel with each other. They are either straight, as in the Grasses, &c. (*fig.* 40, *b.*), when the leaf is commonly linear; or by their gradual divergence they become curved, as in the Convallariæ (*fig.* 44, *b.*), when the outline of the leaf may vary from *lanceolate* to *oval*, *ovate*, *obovate*,

Fig. 44.



or *orbicular*, according to the mode and the degree of the spreading of the veins.*

54. The margin of a leaf, especially of a netted-veined leaf, is seldom perfectly even, or, as botanists say, *entire*. It is frequently notched, toothed, or cleft in various degrees; and an infinite variety of shapes result, for the designation of which numerous terms have been devised. These terms arose from the supposition that a leaf is originally a plane, entire surface, cut by some unknown cause into teeth, notches, lobes, &c. This phraseology is still retained, although the idea upon which it is founded is abandoned.

The general outline or circumscription of a leaf is governed by the disposition of its frame-work; the apparent division or incision of its margin depending chiefly on the degree of development of its parenchyma or cellular portion.

In the leaf-stalk, the frame-work consists of a single bundle of fibres and vessels, imbedded in cellular integument. The lamina consists of the same parts in an expanded state. If, therefore, when the fibres spread there is only sufficient parenchyma to form a coating for each vein and its branches, a leaf like that of the yellow Water Ranunculus† (*fig*. 45, *a*.) will be produced. The leaves of the white-flowered Ranunculus,‡ a more common species than the preceding, exhibit a similar conformation: such leaves are said to be *filiformly dissected*. The frame-work remaining the same, we observe a further development of parenchyma in the emersed leaves of the same plant, the spaces between the ramifications of the principal veins being filled by it (*fig*. 45, *b*.). Such leaves, being apparently divided nearly to the base into several portions, are said to be *parted*. When, by a more copious formation of parenchyma, the principal divisions of a parted or divided leaf grow together for a part of their length, a *lobed* leaf, like that of Ranunculus recurvatus results, (*fig.* 45, *c.*). If the whole space between the lobes be supplied with parenchyma, as in the lower leaves of R. abortivus (*fig.* 45, *d.*), a rounded leaf is produced; the *crenated* margin arising from the absence of parenchyma at the very extremities of the veins. The Ranunculus or Crow-foot genus, from which the foregoing illustrations are taken, exhibits all the intermediate forms between an entire and a filiformly dissected leaf; indeed a large part of the series is often presented by a single plant. The difference is attributable

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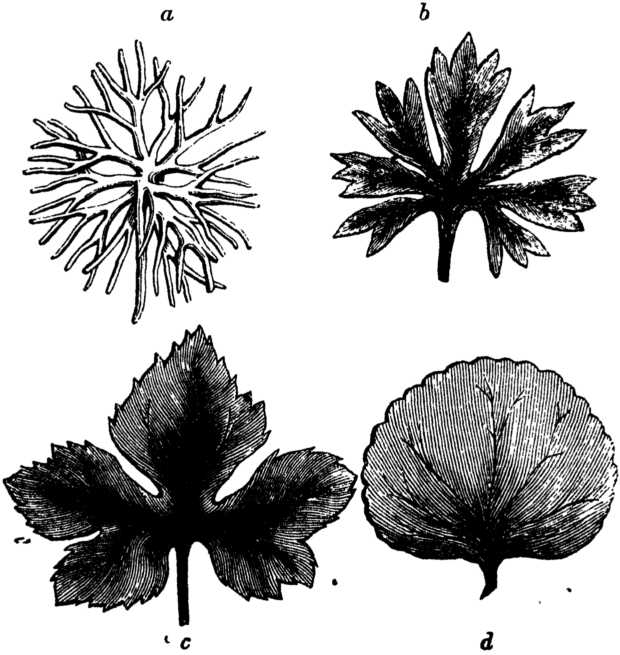
* For an explanation of these and all other terms employed to express the shape of leaves or of any other expanded surface, see Glossology, Chap. VII.

† R. multifidus, *Pursh*;—R. Purshii, *Hooker*.

‡ R. aquatilis, *Linnæus*.

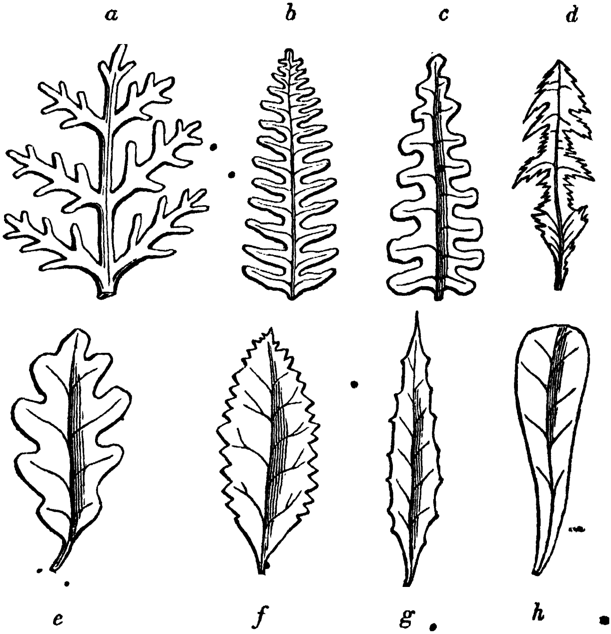
Fig. 45.



to the parenchyma alone, the arrangement of the framework being similar in both, *i. e.* belonging to the radiated form.

The subjoined series of figures, mostly taken from well-known plants, illustrates the division and toothing of feather-veined leaves. The terms applicable to each are explained in the chapter on Glossology.

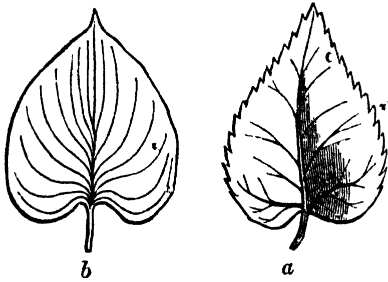
Fig. 46.



Parallel-veined leaves are very seldom toothed, or in any manner divided.

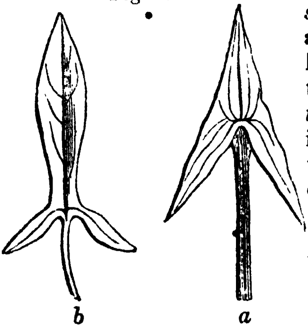
55. The sinus observed at the base of many leaves, is owing, in the reticulated form, to the extension of the secondary veins in that direction (*fig.* 47, *a.*), and

Fig. 47.



in parallel-veined leaves, to the unusual curvature of the lower veins near their origin; as in *fig.* 44, *a*, or more strikingly in Calla palustris (*fig.* 47, *b*.). Such leaves are said to be *cordate* or *heart-shaped*, where the lobes are rounded as in these instances.

Fig. 48.



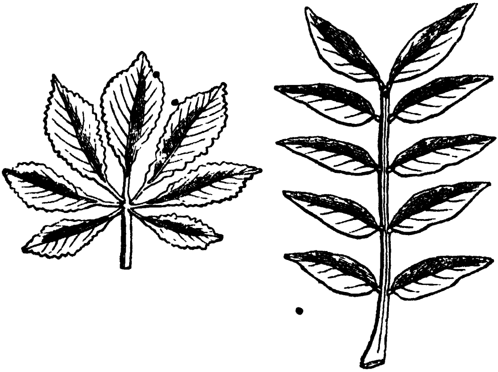
If the lobes are sharp-pointed and directed backwards, the leaf is termed *sagittate* or *arrow-shaped*, as in *fig.* 48, *a*: if the lobes are turned outwards, the leaf is said to be *hastate* or *halbert-shaped* as in *fig.* 48, *b*. A sinus at the apex of a leaf results either from the disproportionate extension of the upper veins, or in radiated leaves from the shortening of the middle vein and the unusual elongation of the lateral ones.

The undulated and crisped surface of some leaves is the result of a cause exactly opposite to that which produces lobes and sinuses, viz. the disproportionate production of parenchyma. (*Ex.* Mallow, and some varieties of the cultivated Cabbage and Lettuce.)

The leaves of all Flowering plants are furnished with veins, yet they are invisible in succulent plants, being buried in pulp, and are often scarcely to be detected in those of a firm and leathery texture: such leaves are said to be *hidden-veined;* being never truly veinless, as is sometimes stated.

56. A *compound* leaf is characterized by having the lamina, or each of its divisions, articulated with the petiole; the pieces which compose such a leaf, receiving the name of *folioles* or *leaflets*. All the forms of compound leaves may be reduced to two kinds; the digitate and the pinnate. They are *digitate* when all the leaflets stand on the end of the petiole, as in the Horse-chestnut (*fig.* 49, *a.*), the Clover, Lupine, &c. They are pinnate (*fig.* 49, *b.*) when the leaflets are placed along the sides of the common petiole.

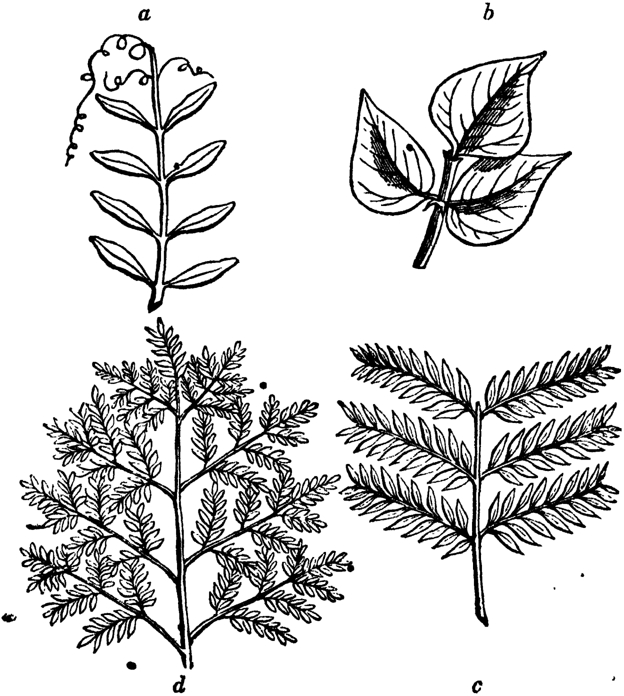
Fig. 49.



Digitate leaves correspond to the radiated form of simple leaves, and pinnated ones to the feather-veined modification. We shall at once comprehend the analogy of a digitate leaf with a radiated simple leaf, by comparing those of the Horse-chestnut (*fig.* 49, *a.*) with the Maple (*fig.* 39, *b.*). We have only to conceive the feather-veined lobes of the latter to be separated quite to the base and articulated with the petiole, and a digitate leaf would be produced. Or, *vice versa*, if we conceive the leaflets of the Horse-chestnut to lose their articulation, and grow together for a part of their length, a radiated leaf would be formed similar to that of the Maple except in the number of its lobes. Thus, as we have before remarked, a radiated leaf may be considered to result from the union of several feather-veined leaves.

The relation which a feather-veined leaf sustains to a pinnated one, is evident on comparing with the latter a series of such leaves as are represented in *fig*. 46. In the latter case, the midrib only expands into lamina at the origin of the primary veins, and these being jointed on the midrib, or, as it now becomes, common petiole, an *abruptly pinnate* leaf results. When the extremity

Fig. 50.



of the petiole also bears a leaflet, as in the common Locust, the leaf is said to be *impari-pinnate*, or pinnate with an odd leaflet. Sometimes the petiole is continued beyond the leaflets in the form of a tendril, as in the Pea tribe (*fig.* 50, *a.*). Leaves are said to be *oppositely* or *alternately pinnate*, according as the leaflets are situated opposite to, or alternate with each other.

The number of leaflets also varies greatly. There may be a single pair only; or a single pair with a tendril, as sometimes happens in the Pea tribe; or a single pair with an odd leaflet (*fig.* 50, *b.*), which is very common in the last named tribe. The latter form is called a *ternate*, but more definitely a *pinnately trifoliolate* leaf; being distinguished from a digitate leaf of three leaflets (*digitately trifoliolate*), in which the several leaflets are articulated with the very summit of the petiole (*Ex.* Clover). We sometimes meet with compound leaves having a solitary leaflet; this happens in the Orange genus, and in a species of Rhynchosia, called on this account R. monophylla. The lamina being jointed with the petiole, such leaves are as truly compound as any of the foregoing examples. We can only judge from analogy whether these belong to the digitate or pinnate series, but the same species of Rhynchosia sometimes produces lateral leaflets, and the leaf is thus proved to be a *pinnate leaf* reduced to *a single leaflet!*

When the primary veins arise from the side of a petiole or midrib, as in an ordinary pinnate leaf, but, instead of bearing a single lamina, serve as petioles along which the limbs of the secondary veins are arranged, a *bipinnate* or *twice-pinnated* leaf is produced, as in the Honey-locust and many Acacias (*fig.* 50, *c.*). Even the third order of veins may form the leaflets, and a *tripinnate* leaf is the result, as in *fig.* 50, *d.* If the division be carried still further, we term the leaf *decompound* or *supradecompound*, whatever may be the extent of division. In all these cases, the secondary petioles are jointed on the main one; and when the leaf falls from the stem, the leaflets also separate at these joints.

Compound leaves are confined to those of the netted-veined kind, or, in other words, to Exogenous plants: parallel-veined leaves are sometimes divided, but are never jointed; consequently truly compound leaves are unknown in Endogenous plants.

57. The *petiole*, or support of the lamina, is a part of the leaf, and not of the stem as Linnæus supposed. It consists principally of cellular integument, through which the bundles of spiral vessels and woody fibre pass before they spread into the lamina.

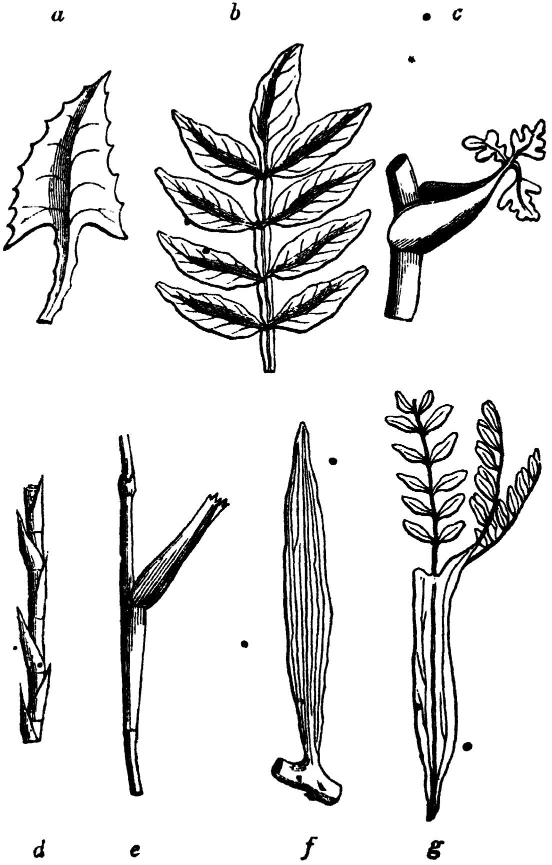
The petiole varies much in length; being often quite short, or wanting altogether, while in some Palms it is 12 feet long. The slender leaf-stalks of the white Water-lily, whose leaves float on the surface of the water, sometimes attain the length of eight or ten feet. Petioles are usually cylindrical, or slightly channelled above; those of the Poplar, however, are very much flattened at right angles with the lamina, so that the slightest breath of air sets the leaves in motion.

The petiole is sometimes furnished with a leaf-like border, in which case it is said to be *winged* or *margined* (*fig.* 51, *a.*). In Lathyrus latifolius, a plant of the Pea tribe quite common in gardens, the whole stem is margined in this manner. In compound leaves, this border is interrupted, where the leaflets arise, as in Rhus Copallina (*fig.* 51, *b.*). Occasionally all the leaflets of such a leaf are abortive, when the margined petiole might be mistaken for a lamina; these have been called *lomentaceous* leaves.

The base, or end of the petiole which joins the stem, is generally somewhat swollen, especially on the lower side; sometimes it clasps or surrounds the stem wholly or in part, as in the Crowfoot tribe (*Ranunculaceæ*), or, still more remarkably, in Umbelliferous plants, in which the whole petiole is frequently flat and membranous; so that were it not for the lamina it bears, its true nature would scarcely be suspected (*fig.* 51, *c.*). The scales which many stems bear in the place of leaves, as those of Monotropa, Orobanche, and Elytraria (*fig.* 51, *d.*), are the bases of petioles destitute of lamina.

The petioles of Grasses are always *sheathing*, and in descriptive botany are usually called *sheaths* (*fig.* 51, *e.*). Sheathing petioles are very common in Endogenous plants, and often the lamina wholly disappearing, the sheath only remains.

Fig. 51.



It happens sometimes when the lamina is abortive, that the petiole spreads out into a leaf-like organ, taking the place of the true leaf. In this state it is called a *phyllodium* (*fig.* 51, *f, g.*). Nearly all the New Holland Acacias bear phyllodia instead of leaves. We know that they are not true leaves, because the young plants sometimes exhibit a pinnated lamina, as in other Acacias. Their edges also are presented to the earth and sky, and not their surfaces as in true leaves. Moreover, being mere dilatations of the petiole, they are parallel-veined, although they occur in plants of Exogenous growth.

Several botanists suppose the leaves of most Endogenous plants to be dilated petioles without limbs, and some circumstances render this opinion probable. Thus, the leaves of the Arrowhead (*Sagittaria sagittifolia*) commonly have both a petiole and limb; but sometimes, while the latter disappears, the former becomes flattened and leaf-like. Occasionally all the gradations between a true lamina and a dilated petiole are seen in this plant, growing on the same root.

The cylindrical and hollow leaves of the Hyacinth, Onion, &c. are doubtless petioles without limbs; and perhaps those of Iris are of the same nature. After all, this question is of little consequence, for the lamina is nothing more than an expanded petiole, and a petiole is merely the unexpanded portion of the lamina.

The branches of the petiole in a compound leaf, are called *petiolules* or partial leaf-stalks.

58. The usual appearance and general symmetry of leaves is occasionally interfered with from various causes, and some uncommon modifications are produced, which, being exceptions to general rules, require a separate notice. Usually, the two sides of the lamina are equal and symmetrical, but sometimes one side is considerably smaller than the other, owing to some unknown cause, acting however uniformly upon all the leaves of the plant; such leaves are called *oblique* or *inequilateral.* (*Ex.* Begonia obliqua, *fig.* 52, *a.*) The symmetry of compound leaves is often destroyed, either by the non-development of one or more leaflets, or by their unusual diminution of size.

Extreme succulence often renders the margins and surfaces of a leaf undistinguishable, producing very singular forms, as in the several kinds of the Ice-plant. Other variations result from a nearly opposite cause, viz. the suppression of parenchyma, and the hardening of the veins. In this way spines are formed, as on the edges of the leaves of the Holly and Thistle, in which the hardening is confined to the lobes. The radiated spines of the Barberry are caused by the hardening of the primary veins and the total suppression of the parenchyma of the original leaves. The lower part of the young stem generally furnishes a few spinose leaves, showing how this curious transformation takes place.

59. Still more strange modifications of leaves sometimes result from the cohesion of parts which are generally distinct. It is well known that organs which stand very close to each other are liable to cohere or grow together; as leaves to each other and to the stem, and fruits to each other and to the neighboring parts of the flower, many examples of which will be noticed in the proper place. Accidental instances of this kind occasionally occur, such as the union of neighboring leaves, double apples, &c.; but these being strictly accidents, are, of course, seldom met with. But in other instances such unions take place at a very early period, when the organs are yet scarcely visible; in these cases they are of constant occurrence, owing to the uniform operation of the cause, whatever it may be, which produces the union. They are appropriately termed by De Candolle, *constant accidents;* since, although contrary to the natural course of things, they occur uniformly in each species. Many unusual appearances may be explained by attention to this circumstance. We have seen (*fig.* 43.) how a leaf like that of the common Mallow may become *peltate* or shield-shaped. The species of Hydrocotyle or Marsh Penny-wort show this transformation very beautifully, as is seen in *fig.* 52, *b*, *c*, *d*.*

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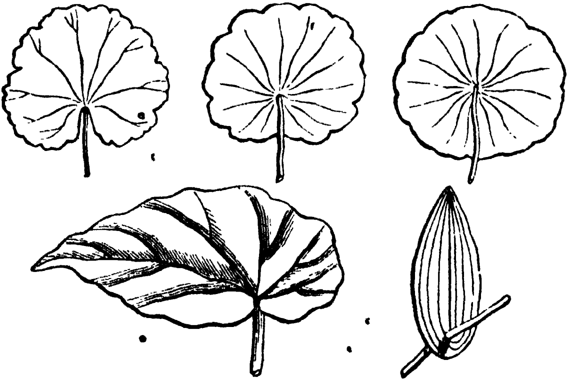
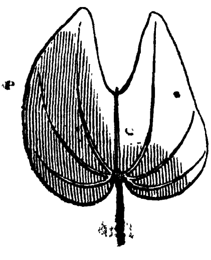
* *Fig.* 52, *b*, a leaf of Hydrocotyle Americana; *c*, H. umbellata; *d*, H. interrupta.

Fig. 52.



In like manner the posterior lobes of some sessile leaves grow around the stem and cohere together, as in Streptopus amplexifolius (*fig.* 52, *c.*) and several species of Uvularia: such leaves, appearing to be perforated by the stem, are said to be *perfoliate.* The bases of opposite leaves not unfrequently grow together, especially the upper pairs, as in several species of Honeysuckle (*Lonicera*): leaves of this kind are said to be *connate*, and the arrangement of the veins sufficiently distinguishes them from the former case.

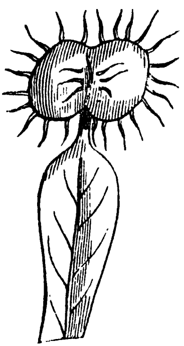
Fig. 53.



Curious instances of twin leaves occur in nearly all the species of Bauhinia, a genus appropriately dedicated by Linnæus to the brothers John and Caspar Bauhin, who unitedly wrote and published the *Pinax plantarum.* These leaves (*fig.* 53.) are evidently composed of two leaflets, more or less united by their inner margins.

Leaves also grow to other organs; sometimes by the midrib, as the flo-

Fig. 54.



ral leaf of Tilia adheres to the flower-stalk; and sometimes sending down a leafy border along the stem, as in the *decurrent* leaves of the common Mullein. In these and all similar cases, however, the aspect of leaves is slightly affected; but the most puzzling forms are seen, when the petiole and the lamina at the same time undergo some unusual transformation. Thus the sensitive appendage to the leaves of the Fly-catcher of the Southern States (*Dionæa muscipula*, *fig.* 54.) is the true lamina, articulated upon the summit of a dilated, leaf-like petiole.

If this view be correct, it will serve to explain the nature of the hollow leaves of the Sarracenia or Side-saddle flower; of which several species are found in the Southern States, and one (*S purpurea*, *fig.* 55.), with its leafy cups half filled with water and dead insects, abounds in the bogs of the Northern and Middle States. If we conceive the dilated petiole of Dionæa to be folded inwardly and united at the edges, a leaf like that of Sarracenia would be formed. The pitcher, then, may be considered as a hollow petiole, with a leafy margin or wing on one side, and the hood or lid (which in other species more nearly resembles a lid) is the lamina.

Fig. 55.

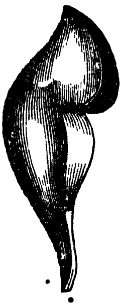
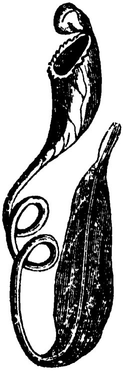


Fig. 56.



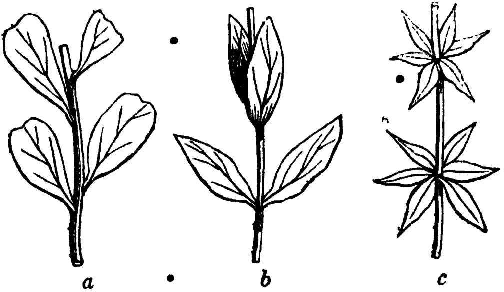
The still more strange leaves of Nepenthes, the Pitcher-plant of India (*fig.* 56.), may be similarly explained. The petiole where it arises from the stem is round, or of the usual shape; soon it expands into a leaf-like organ, which is probably of the nature of a phyllodium (57); next, it becomes again round and slender, like a tendril; and lastly, expands into a pitcher, to which the lamina, at the summit, forms a lid. The pitcher is partially filled with nearly pure water, which is not collected from without as in the Sarracenia, for the lid accurately closes the opening, but is deposited by the plant itself. We are not to suppose that Nepenthes or similar plants (there being several instances of the kind) have any peculiar property in this respect; the ordinary perspiration of leaves in such a situation, where there can be no loss by evaporation, will account for the accumulation of water in these pitchers.

60. The position of leaves on the stem is next to be considered. With regard to the stem itself, leaves are *radical* when they arise from the stem at or beneath the surface of the ground; *cauline*, when they arise along the main stem; *rameal*, when they belong to ordinary branches; and *floral*, when they stand on the flower-bearing branches. The size of leaves often varies with their situation, the radical ones being usually largest and the floral ones smallest: not unfrequently their shape also differs. With regard to their succession, the earliest-formed leaves are those which were enclosed within the seed; these are called *seminal:* those which immediately succeed the first, are called *primordial*. The seminal and primordial leaves decay as soon as others arise to take their place; their shape and appearance is usually quite different from the succeeding or *ordinary* leaves.

As to the situation of leaves with respect to each other, it may be observed that they are always arranged in some particular order, which is uniform in each species. It has already been stated that leaves always rise from the nodes, just below a regular leaf-bud. They are placed either *alternately* one above another (*fig*. 57, *a*.); or in pairs one on each side of the stem, in which case they are said to be *opposite* (*fig*. 56, *b*.): when more than a single pair of leaves arise apparently from the same node, they are *verticillate* or *whorled* (*fig*. 57, *c*.).

Respecting the first mode of arrangement, it is to be noticed that the leaves are seldom placed one above the other on exactly opposite points of the stem; but usually the second leaf is a little to the right or left of the opposite point, and the third is in like manner a little on one side of the first, &c. : so that tracing along the bases of the leaves of a branch, we describe a simple spiral line. When the leaves are quite close the spiral arrangement is very evident; when widely scattered it is much less so.

Fig. 57.



In the Apple and Pear-tree we perceive that the spire consists of five leaves; that the sixth, or commencement of the second series, covers the first, the seventh the second, &c.: this is the most common arrangement of alternate leaves. Some leaves exhibit a double or even a triple spiral disposition.

The spiral arrangement of leaves is a beautiful provision for securing the symmetry of the branches; the wood being formed by the action of the leaves and leaf-buds, if these were not placed in regular order over every part of the circumference, more wood would be deposited on some sides of the stem than on others. So, when the spire is reduced to its simplest state, that of two leaves, or in other words, when the leaves are alternate in the strict sense of the term, the stem is usually two-edged or flattened from this very cause.

In opposite-leaved plants, the pairs are placed in an alternate manner with respect to each other, that is, the second pair is at right angles with the first, the third pair exactly over the first, and the fourth over the second. It results from this disposition, that the branches of opposite-leaved plants are commonly more or less four-sided (*Ex.* Labiatæ), instead of being cylindrical as in alternate-leaved plants.

The whorled arrangement does not essentially differ from the opposite, which may be considered as a whorl reduced to a single pair.

Although the relative position of leaves is generally definite and uniform in each species, yet the symmetry is occasionally disturbed. The Honeysuckle under ordinary circumstances bears opposite leaves, but when it grows very rapidly they occasionally become alternate. On the contrary, when alternate-leaved stems are very much contracted between the nodes, the leaves appear opposite or whorled. In some plants the lower leaves are whorled, the middle ones opposite, and the uppermost alternate. From these circumstances, some botanists have inferred that the alternate or spiral is the natural or *normal* mode of arrangement, becoming manifest whenever the stem grows uninterruptedly; but when, from some cause, the extension of the stem is periodically interrupted, the leaves appear in pairs; if its growth be checked until three or more leaves are formed, they become whorled.

It is found, almost without exception, that whenever both opposite and alternate leaves occur together in plants of Exogenous growth, the lower are opposite, and the upper alternate; in Endogens, on the contrary, the lower leaves are almost always alternate, the uppermost being occasionally opposite or whorled. Desfontaines, in noticing this economy, connected it with another fact, which will be more particularly considered hereafter, viz.: that the seminal leaves of Exogens are always opposite, or whorled, which is nearly the same thing; and those of Endogens, if more than one, are alternate. Hence it may plausibly be inferred that the natural position of leaves in Exogenous plants is opposite, and in many families this arrangement is rigorously adhered to, as in the Pink tribe, the Mint tribe, &c.; but in other cases, by the division or extension of the nodes from some unexplained cause, they assume the alternate arrangement. Endogenous plants, considered in this view, are originally alternate-leaved; the opposite or whorled arrangement, which but rarely occurs, resulting from the non-development of one or more internodes

A third, but more unusual mode sometimes occurs, that of *fascicled* or tufted leaves. This, however, is only an accidental deviation to which either system is liable. Leaves are never actually produced side by side, although when a digitate leaf is sessile the several leaflets present this appearance. The true nature of such leaves is known by analogy only. In the Barberry the real stem-leaves are changed into spines (58), and the apparent bundle of new leaves is a very short branch. In the Pine also the seeming fascicle of leaves is a young branch, the little sheath enveloping the base of the fascicle being the rudiment of a true leaf. During the growth of the plant some of these imperfect branches lengthen, and the spiral disposition of the leaves is thus rendered manifest.

61. At a definite period, varying in different plants but nearly uniform in each species, leaves gradually lose the power of performing their office,—their color at the same time changing to some shade of red, yellow, or brown,—and finally those articulated with the stem separate at the joint and fall away; the others wither and decay on the stem.

In view of their duration, three kinds of leaves may be distinguished, viz.:

1st. *Fugacious*, when they fall off soon after their first appearance, as in the Prickly-pear.

2d. *Deciduous*, when they fall in the autumn, which is the most common case.

3d. *Persistent*, when they remain beyond a single season, and until after the appearance of new leaves, so that the stem is never leafless; as in the Holly, the Pine, &c.: such plants are called *Evergreens*.

The fall of the leaf is not attributable to the action of frost; since the trees of this latitude transported to warmer climates lose their leaves at stated periods. It has been attributed to the consolidation of the parenchyma by the gradual accumulation of solid matter, carried in with the sap and left by evaporation. This very well explains the death of leaves, but does not account for their fall, which, although accelerated by various causes, takes place with great uniformity in all Exogenous trees and shrubs, but not in those of Endogenous growth. The following is the only satisfactory explanation of the fall of the leaf which has yet been offered.

When the leaf and stem are both growing and in a healthy state, the base of the former and the branch that bears it both increasing at the same rate, there is no interruption to their mutual adaptation. But when at length the full-grown leaf loses its vigor by the deposition of extraneous matter in its substance, its base can no longer adapt itself to the growing branch, which is rapidly increasing in diameter by the formation of wood. The leaf is consequently disjoined at the articulation by the rupture of the connecting vessels, and drops off.

This view is given by Prof. Lindley, and does not materially differ from that of Du Petit Thouars. It accounts for the early fall of the lower leaves of herbaceous plants, and for the fall of the old leaves of Evergreen trees while the wood of the ensuing summer is forming. Endogenous stems admitting of no increase in diameter, their leaves consequently do not fall, but simply perish and decay on the stem.

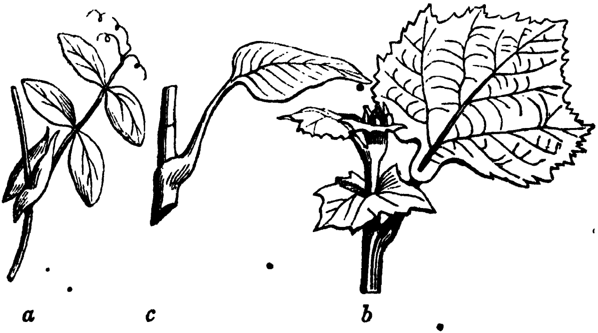
SECT. VI. *Of Stipules and Tendrils.*

62. STIPULES are small leaf-like bodies, situated one on each side of the base of a petiole. Their nature is not very well made out. Stipules, tendrils, spines, &c. were formerly included under the general names of supports or appendages of plants; but tendrils and spines are now known to be modifications of leaves and

branches, and not special organs. It is very probable that stipules also are modified leaves. Thus, they are generally green and of a leaf-like texture, being sometimes as large as the leaves themselves, and in the Pea even larger. Indeed, in one plant of the Pea tribe the leaves are all changed to tendrils, and their place is supplied by a large pair of stipules. The veins of stipules, when they have any, are arranged in the same mode as those of the leaves; and they produce leaf-buds in their axils in several Willows, which seems to decide the question.

All stipules have not a leaf-like texture, being frequently membranaceous and sometimes scaly; occasionally they are mere bristles or points, and like leaves are sometimes changed into spines. In the Cucumber tribe and in some other instances they change into tendrils. Thus they are seen to undergo all the ordinary modifications of leaves, from which they differ however in one constant character, viz.: their situation in pairs at the base of a true leaf.

Fig. 58,



The Pea tribe presents numerous instances of stipules in their ordinary leaf-like state (*fig*. 58, *a*.). They agree with leaves also in their tendency to cohere with one another and with neighboring organs, thus changing their natural appearance. In the Rose, the common species of Clover, &c., they adhere to the base of the petiole, one on each side. In other cases their outer edges growing together, there seems to be a single stipule opposite the leaf (*Ex.* Platanus, *fig.* 58, *b.*). Their usual appearance is sometimes still further changed by the union of the inner edges also, when they form a kind of membranous sheath for the stem just above the leaf, as in Polygonum and all the Buckwheat tribe (*fig.* 58, *c.*); such stipules are called *ochreæ*, and also *intrafoliaceous* stipules. Opposite-leaved plants seldom have stipules, but when they do (as in Rubiaceæ), it often happens that the two contiguous stipules of each pair of leaves unite by their edges, forming seemingly but a single pair, common to both leaves. These are called *interpetiolar* stipules.

The several leaflets of a compound leaf are sometimes furnished with little stipules, as in the Bean; these, to distinguish them from the stipules of leaves, are called *stipulules* (*fig.* 50, *b.*).

The presence or absence of stipules is nearly uniform in the same family. Thus, with one or two exceptions, all plants of the Rose tribe, the Pea tribe, &c. have them. The Cruciferæ, Ranunculaceæ, the Pink tribe, &c. are without them, and therefore their leaves are said to be *exstipulate*. In many plants, however, they fall off at an early period (*Ex.* Magnolia), and in several cases being joined to the petiole they become inconspicuous.

It is said that no Endogenous plants are furnished with stipules, yet they seem to exist in the Pond-weeds (*Potamogeton*); and if the tendrils of Smilax (63) are not modified stipules, their nature is not yet understood.

When the texture of stipules is leaf-like, they perform the ordinary functions of leaves; but in other cases their office, if they have any in particular, is unknown. The large membranaceous stipules of the Magnolias and the Tulip-tree envelop the young leaves in the bud, but in most cases they are much too small to subserve this purpose.

63. **Tendrils** are slender, thread-like prolongations, capable of clasping spirally, or fixing themselves to neighboring bodies. By their aid feeble and climbing

stems are enabled to sustain themselves upon more firm and sturdy plants. They are not peculiar organs, for almost any part of a plant may become a tendril. The extremity of the petiole often becomes a tendril in the Pea tribe (*fig.* 50, *b.*). In the genus Gloriosa (lily-like plants of warm climates) the lamina itself is prolonged into a tendril: in the Gourd or Cucumber tribe the tendrils appear, from their situation to be transformed stipules; but it is remarkable that there is only a single one to each leaf. In Smilax they are transformed stipules, cohering with the base of the petiole; although stipules have been denied to Endogenous plants, yet it will be remarked that the foliage of Smilax resembles that of Exogens in several other respects. In the Vine a portion of the flower-bearing branches are transformed into tendrils.

CHAPTER III.

OF NUTRITION IN FLOWERING PLANTS.

64. THE offices of each of the organs noticed in the preceding chapter, so far as they are known to us, having been already indicated,it remains in the present chapter to consider their combined action in relation to *nutrition*, or the conversion of unorganized matter into their own proper nature. Introductory to this subject, we must briefly notice the powers by which the vegetable apparatus is put in action; and finally we are to consider several curious phenomena indirectly connected with nutrition, which, as they do not appertain to any single organ, could not properly be treated of in the preceding chapter.

This subject presents a wide field of inquiry no less interesting to the practical cultivator than to the student of nature. It abounds in impressive illustrations of the faultless skill and wisdom of the Deity in the production of the most grand and highly important results by a few simple and apparently insignificant means.

Our limits restrict us to a cursory account of the leading phenomena of vegetable life, divested of all unnecessary detail.

SECT. I. *Of the Powers which Plants possess for the performance of their Functions.*

65. Many vegetable actions arise from certain properties inherent in the tissue of a plant, being equally common to it both in a dead and living state; these are called *properties of tissue*. The most important of these are extensibility, elasticity, hygroscopicity, and endosmosis.

1st. *Extensibility* belongs in some degree to all the parts of a plant while in a growing state. Not unfrequently a young branch extends in the course of a few weeks from half an inch to several feet in length, at the same time increasing in diameter at a corresponding rate. A leaf at its earliest appearance is a minute scale, but a week or two is generally sufficient for its full development. The same rapid growth takes place in almost every organ. This increase is owing partly to the deposition of new matter, and partly to the extensibility of the tissue.

The cuticle of a growing stem is subject to a rapid increase, and its expansion depends chiefly, if not entirely, upon its extensibility, which is, however, confined within certain limits. Newly-formed tissue is most extensible, as the rapid elongation of young branches sufficiently proves.

2d. *Elasticity*, or the power of suddenly assuming a new direction on the withdrawal of a restraining force, requires to be noticed; its effects having often been mistaken for cases of irritability.

In the Parietaria, an humble weed of the Nettle tribe, the filaments (127) are curved or coiled inwardly in the flower-bud, and confined in that situation by the calyx. These filaments, when fully grown, act like little springs, suddenly forcing open the calyx by their elasticity. A similar contrivance exists in the Kalmia or American Laurel. Before the flower opens, the summits of the ten stamens (126) are placed in the same number of little pouches on the side of the corolla, and retained by a glutinous substance. When the corolla opens, the filaments are curved outwardly and placed in a state of tension; their elasticity at length frees them from the corolla, and they fly upwards with a sudden jerk. We shall have occasion to allude to the object of this contrivance in another place. It has been stated * that the stamens of the Kalmia start up when their base is touched with a sharp point, like those of the Barberry; but this is incorrect, the movement being wholly mechanical. Several flowers open elastically, and among fruits the Balsam and Touch-me-not are familiar examples.

3d. *Hygroscopicity*, or the property of absorbing or giving out moisture according to the nature of the body and the state of the surrounding atmosphere, is a property common both to organized and unorganized matter. Young tissues which are not filled up with foreign substances are most active in taking up moisture; thus the spongelets of roots are eminently hygroscopic, the bark much less so. Sap-wood absorbs readily. Young branches of Willow or Poplar stuck in damp soil will take up sufficient moisture to keep the branch alive until new roots are formed. Heart-wood, on the contrary, being filled with solid matter, is not hygroscopic; hence it is more durable as timber, especially when exposed to humidity. Many apparently spontaneous movements are caused by alternations of moisture and dryness; thus the beard of the Oat twists by losing, and untwists by absorbing, moisture; and the teeth of the fruit-case of Mosses (186) move from the same cause.

The absorption of moisture is controlled by a very remarkable power, lately discovered by M. Dutrochet, a distinguished French physiologist, called,

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* See *Library of Useful Knowledge*, Art. *Botany*, p. 79. Even De Candolle seems not to have understood this phenomenon when in alluding to some undoubted instances of vegetable excitability he says, "Dans les géranium et les kalmia, les filets se courbent pour poser l'anthère sur le stigmate."—*Physiologie Végétale*, II, p. 517.

4th. *Endosmosis.* This power undoubtedly exercises an important influence in vegetable physiology as well as elsewhere. The general rule in respect to its operation is, that if two fluids of unequal density be separated by a membrane, even destitute of visible pores, the lighter fluid passes through the membrane, mingling with the denser. A simple experiment will illustrate this. If a short tube, or a phial with the bottom broken off, be covered at one end with any vegetable or animal membrane, nearly filled with a solution of gum arabic, and half immersed in water, the denser mucilage will attract the water through the membrane, and the tube will be filled. A small portion of the denser fluid also passes outward and mingles with the water, but the preponderance is greatly in favor of the mucilage, and the denser the fluid the stronger its attraction upon the water. Let the experiment be reversed by filling the tube with water and immersing it in a vessel of mucilage, when, in accordance with the same rule, the water will slowly sink in the tube, which will at length nearly empty itself.

This power offers a ready explanation of many acts of vegetable life which were formerly altogether inexplicable. Several instances will be adverted to in due time. We may here adduce a single illustration, viz., the growth of fruits. When a fruit, such as the peach or plum, begins to enlarge, its cells are filled with a fluid denser than the sap; by the property of Endosmosis, therefore, they attract a large portion of the neighboring sap into the fruit, which in consequence becomes juicy. The density of the fluid is kept up by the continual evaporation of its watery portion, and thus the fruit is enabled to appropriate to itself a great part of the food of the plant, which it changes into a pulp. In this, no doubt, we have the true explanation of the fact, that plants are weakened and their growth checked by bearing fruit; and that plants which flower but once (annuals and biennials) die for the most part soon after the maturation of their fruit.

66. These properties alone are insufficient to carry on any of the processes of vegetation, existing as they all

do in a dead plant as well as in a living one: the principle of life is requisite to control and modify them. We know nothing of the nature of life. It is something which sets the machine in action, preserving it from the chemical changes to which dead matter is liable, and enabling it to be influenced by external agents. This property, or power, is called *excitability*. It acts only upon the elementary tissues of plants, and does not usually give rise to sensible motions; its presence, therefore, is only known by its results. Thus, the sap ascends rapidly in a living stem, but not in a dead one; and light causes living leaves to decompose carbonic acid gas, but has no such action upon dead leaves.

Excitability resides principally in the cellules. If we cut out a piece of the stem of the Lettuce, or any other milky plant, the juice comprised in the cellules of the bark runs out from both extremities of the portion; proving that it is moved by a force residing in the cellules themselves, and not by a power exerted from above or below; for in the latter case the juice would flow from one extremity only. Neither does it exude by its weight, because it flows as readily from the uppermost as from the lower extremity. Moreover, if the plant be destroyed, either slowly by the action of poisons, or suddenly by a shock of electricity, the milky juice will not flow out when the stem is wounded.

An excessive degree of excitability occasionally produces sensible movements of the organs of plants, by the influence of external agents. Thus some leaves collapse in the absence of light, and expand again upon its return. The leaf of Dionæa (*fig.* 55.) closes suddenly and with considerable force when its upper surface is touched; and a slight shock, or even a drop of any corrosive fluid, causes the leaflets of the Sensitive plant to collapse. This property has been termed *irritability*, but all these instances are probably extreme cases of simple excitability. If then the term irritability be employed, we should be careful not to confound it with the *sensibility* of animals, a faculty which depends upon a nervous system, and therefore has no existence in plants. Some persons have attributed sensibility and a nervous system to plants; but it would indeed be an undesirable and cruel gift to endow them with the faculty of experiencing pleasure and suffering pain, when by their nature they are unable to seek the one or to avoid the other.

67. The joint action of at least two external agents, viz.: heat and light, is essential to vegetation. These agents seem to act chiefly as excitants to the living principle. Heat excites the action of buds in the spring, causing them to unfold; it also promotes evaporation from the surface of leaves, in both cases indirectly effecting the ascension of the sap. The light of the sun enables green-colored parts to decompose carbonic acid, and to fix the carbon in their tissue; it also gives rise to the colors of vegetables.

In conclusion, it appears that the living principle, excited by heat and light, controls and modifies the properties inherent in the tissue of plants; and that by virtue of these powers, severally or jointly, vegetables are enabled to develop their parts, to take in and assimilate their appropriate food, to increase in bulk, and to perform all their different functions.

SECT. II. *Of the Food of Plants, and of Absorption by the Roots.*

68. *The food of plants is introduced into the vegetable system principally by the roots.*

It is by no means difficult to find exceptions to this proposition. Several Flowering plants (such as the Tillandsias of the Southern States, the epiphytic Orchideæ, &c.) grow on the bark of trees, and their roots serving merely to fix them in this situation, they absorb air and moisture by the whole surface of their stem and leaves. Similar instances are extremely common in Flowerless plants, especially in the lower orders of this class; but we do not intend to consider the economy of these plants in the present chapter. All vegetables, perhaps, have the power of taking in moisture by their leaves, yet in ordinary circumstances they absorb very little in this way; and the influence of the atmosphere itself is not so much to furnish food to the plant as to assist in its digestion. The numerous exceptions, therefore, which may be adduced hardly invalidate the rule.

Roots absorb solely by their spongelets or soft growing extremities, as has already been remarked (24). The spongelets have not the power of taking in the smallest quantity of solid matter, even in the state of the finest powder; consequently all the nourishment of plants is received in the fluid form. They are also incapable of selecting the appropriate food of the plant, but absorb whatever fluid is presented, whether it be food that nourishes, or poison that destroys them.

Some fluids, however, are more readily absorbed than others. Water when pure is taken in much more abundantly than the same liquid containing a small quantity of mucilage, although the latter is the more nourishing; and the stronger the mucilage, the smaller the quantity absorbed. Water containing a minute quantity of arsenic or corrosive sublimate is promptly absorbed until the plant is killed; but a strong solution of the same substances is taken in very slowly.

De Candolle accounts for these remarkable facts on the supposition that the minute tubes of the spongelets are soon obstructed by solid matter. The property styled Endosmosis, however, offers a more plausible explanation. The spongelets always contain a quantity of mucilage heavier than the fluid which under ordinary circumstances composes the food of plants; which, being water holding some gaseous, and a minute portion of earthy matter in solution, is therefore attracted into the roots by the denser fluid contained in the spongelets, or, in other words, by the power of endosmosis. In accordance with the law by which this power acts, as given in the preceding section, the denser the ambient fluid, the less will be its absorption, and *vice versa*. The circumstances which regulate this absorption will be considered hereafter.

Roots, it is well known, lengthen chiefly by their lower extremity; consequently, when the spongelets have exhausted the nourishment within their reach, they harden, and produce new spongelets at their points, which extend into a fresh portion of the soil. In this manner—a simple result of their property of elongation by the points alone—roots seek after their proper food. The roots of trees generally lengthen at the same rate as the branches: were it not so, the dense foliage would check the growth of the tree by preventing the rain from reaching the absorbing extremities of the roots. Some plants indeed draw their nourishment from a great distance, having roots many times longer than the stem; those of the Luzerne have been known to extend more than 30 feet.

When the elongation of a root is stopped by any obstacle, its apex sends out rootlets in every direction: those which meet with a fertile soil and abundant moisture elongate rapidly; those which strike into a barren soil either perish or grow very slowly. We have in this the explanation of the faculty which roots seem to possess of roaming in search of nourishment, selecting a fertile, and refusing to penetrate a barren soil.

When vegetation is suspended in autumn, the roots also cease to grow; hence this is the best season for transplantation.

69. *The proper food of plants is water holding in solution a quantity of carbonic acid.*

It is well known that many plants will continue to grow in water alone. Boyle and Von Helmont caused young willows to grow in a quantity of sand of known weight, plentifully supplied with water. When the young plants had increased very considerably, they removed them, and, carefully weighing the sand, found that it was not perceptibly diminished. They inferred from this result that the soil only serves to fix a plant, and that water alone is sufficient for its nourishment. But more careful experiments have demonstrated that water is not sufficient for this purpose; since plants furnished with distilled water in these circumstances do not grow. Seeds will germinate, and bulbs and tubers will grow very well until the nourishment they contain is exhausted, but no further. It may be remarked, that nearly all plants which we are accustomed to cultivate in water, such as the bulbs of the Hyacinth, &c. live upon a stock of nourishment previously accumulated in the root or stem.

Vegetable tissue in its simplest state is composed of three elements—oxygen, hydrogen, and carbon (1); pure water contains the first two of these; and the third, which constitutes a large part of the bulk of a plant, (as may be seen by expelling the other elements from a piece of wood, leaving the carbon or charcoal only,) cannot be derived from water. To suppose that the plant has the power of producing carbon, a simple substance, is a manifest absurdity, although this opinion has been entertained. Sir Humphrey Davy long ago ascertained that roots will not take up a particle of charcoal in powder; but when the carbon combines with oxygen, and forms carbonic acid, it is absorbed by water, and taken in readily by the roots. Water, holding carbonic acid in solution, is therefore the appropriate food of vegetables: young plants supplied with such a solution grow rapidly, but with distilled water scarcely at all: they grow in ordinary water, because it always contains foreign substances, and especially carbonic acid, which is derived both from the air and the soil.

All manures which increase the fertility of the soil either contain this substance ready formed, or carbon; the latter taking oxygen from the air, becomes carbonic acid, which is dissolved by water and absorbed by the roots. Carbonic acid also exists in the air, and is received in small quantity by the leaves; but being absorbed by water, it chiefly finds its way into the vegetable through the roots. Water also derives from the atmosphere a small quantity of oxygen and nitrogen gases; these are likewise taken into the plant. The oxygen gets into the spiral vessels in some unaccountable manner; for it has been proved by recent observations* that these vessels contain oxygen gas more or less pure, which is thus transmitted through the interior of the plant. It is commonly supposed that the nitrogen is of no use to the plant; but however this may be, it is an essential ingredient of several vegetable products.

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* Bischoff, *De vasorum spiralium plant., &c.*, fide De Candolle, *Physiologie Végétale*, I., p. 84.

70. *All the earthy and metallic substances contained in the soil, capable of being dissolved by water, are also carried into the plant, in quantities which depend upon their solubility and their abundance.*

Thus soda is found in marine plants, and potash in those which grow at a distance from the sea-shore. Some Charas, growing in water that contains a small portion of lime, accumulate a large quantity of carbonate of lime beneath the cuticle, forming a thick calcareous deposit. The straw of Wheat and of other Grasses contains so much silex, that their ashes are employed for polishing metallic substances. The cuticle of the common Scouring-rush is also filled with minute particles of silex. The hard rind of the Rattan contains about 80 parts in 100 of the same material, and will even strike fire with steel. The substance called *Tabasheer*,* to which wonderful properties have been attributed, is a siliceous concretion, which forms in the nodes of the Bamboo.

Some aquatic plants accumulate iron, so that in decaying, they leave a sediment of iron-rust in the water. Iron is also sparingly found in most kinds of grain, its quantity varying with the nature of the soil; the same remark being equally applicable to the preceding cases. Copper has been detected in minute quantities in almost every plant that has been tested for it. It is said by M. Sarzeau† to constitute in coffee about 8 parts in a million, and in wheat about 4½ parts in a million; whence it has been estimated that the French consume every year about 8,000 pounds of copper in their bread, and in all Europe about 2,240 pounds are consumed in coffee during the same period.

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* See Dr. Brewster, On the the properties and natural history of Tabasheer, in the *Edinb. Journ. of Science*, XVI., p. 285, (1828). Dr. Brewster thinks silex is an integral element of the plant itself, and not an accidental deposit, and that it probably performs some important function in the processes of vegetable life.

† *Journ. de Pharmacie*, 1830, fide De Candolle, *Physiologie Végétale*, I., p. 389.

Many other simple bodies have been found in plants; thus iodine exists in Sea-weeds, being gradually accumulated from the water of the ocean, which contains a minute portion. Chlorine is found in all marine plants, phosphorus in the Onion, and sulphur in mustard-seed,* in Celery, and in Ginger.

Some persons have supposed that these mineral substances were produced by vegetation, and not derived from without. This opinion is certainly inadmissible so long as their presence can be otherwise accounted for. They are dissolved, we may conceive, in a large quantity of water, and carried into vegetables indiscriminately; and each species, according to its peculiar constitution, retains a portion of one or more of these matters. Thus nearly all plants retain a quantity of potash; Chara retains carbonate of lime; Wheat a small quantity of silex; the Scouring-rush a much greater quantity of this substance; and the Pea and Clover none at all. The immense quantities of water, variously impregnated with foreign matter, which pass through a plant, entering by the roots and leaving again by evaporation from the leaves, is sufficient to account for the presence of all these foreign bodies. A single Sun-flower plant, about three feet high, loses during its ordinary vegetation about 20 ounces of water a day; to supply this loss, at least 30 ounces must be absorbed, as about one-third of all the water taken into a plant is generally fixed in its tissue.

SECT. III. *Of the Ascension of the Sap.*

71. The nourishing fluid taken in by the roots is called the *ascending sap*, or simply the *sap* of the plant. This fluid, it is well known, is carried up into

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* The seeds of Mustard and of some other Cruciferous plants abound so much in sulphur, that they are unfit for making gas for illumination, notwithstanding the large quantity of oil they contain. See *Silliman's Am. Jour. of Science.*

the leaves, where it undergoes certain changes in composition, and is then returned into the bark.

The sap, when first received into the plant free from all accidental mixture, essentially consists of water charged with carbonic acid; but in its passage along the stem it usually becomes impregnated with the various matters it meets with in its course, and thus its properties are somewhat changed. These matters are commonly gum, starch, sugar, or some astringent substance, previously deposited in the stem and now redissolved and taken into the ascending circulation. So the sap of the Sugar-maple is sweeter when drawn from the upper than the lower part of the trunk: that of the Birch is tasteless in the root, but astringent in the upper part of the stem.

72. *The sap rises in the alburnum or sap-wood, and with very considerable rapidity and force.* If we cut across a woody stem when the buds are about to burst into leaf, the sap flows from the whole surface of the alburnum, especially from the outermost layers, but not at all from the pith or bark. It not only ascends perpendicularly, but is diffused laterally, exuding freely from a shallow wound in the stem. This *flowing* of the sap, as it is termed, occurs not only at the season of leafing, but also at the period of the fall of the leaf.

The tissue by which the sap ascends seems not to be very well determined. The prevalent opinion is that it rises chiefly through the woody fibre, but not exclusively; for it passes laterally, no doubt, by means of the cellular tissue. De Candolle thinks that it ascends entirely by the intercellular passages; but if we cut across a vine at the period of the flowing of the sap, it appears to escape by the ducts, whose open mouths are distinctly visible to the naked eye; yet, except at this period, the ducts evidently contain air only.

The sap rises most rapidly when evaporation from the leaves is greatest, and vegetation is in full activity. At this time, there being no accumulation, the sap will not flow when the stem is wounded; but if the leaves be stripped off, the stem is again surcharged with sap, and will flow as in the spring or fall. The celebrated

Dr. Hales undertook to measure the force of the ascension of the sap by its effect upon a column of mercury. He found that the stem of a Vine, not quite an inch in diameter, propelled its sap with a force equivalent to the weight of a column of water a little more than 40 feet high. We may form some idea of this force by considering the height to which the sap rises in our loftiest forest trees.

73. *The sap is put in motion by the expansion of the buds, and by evaporation from the leaves.* The ascension of the sap is not, as is popularly supposed, the cause of the leafing of trees, but the effect. A slow absorption from the roots beyond the reach of cold, continues during the whole winter, and the trunk is therefore gorged with sap. Early in the spring, the heat of the sun causes the buds to swell, and to attract a part of the sap from the tissue in their vicinity. The portion thus deprived of its sap is replenished by the tissue below, which is in its turn filled by the tissue next below it in the same way; and thus the sap, which begins to move in the branches, is at length set in motion throughout the whole trunk.

When the leaves open to the light, the sap which they contain is concentrated by the evaporation of a great part of its water; and being thus rendered more dense, it deprives by endosmosis the tissue below of its thinnest portion, which in turn acts in like manner upon the subjacent tissue, and the sap is put into active motion quite down to the spongelets. Evaporation from the leaves not only causes the ascension of the sap, but also controls absorption by the roots; thus absorption is most rapid during a hot, dry day, when evaporation is most copious.

SECT. IV. *Of Digestion, and the Action of Leaves upon the Atmosphere.*

74. The process of digestion in vegetables consists of three parts, which, although they are all carried on simultaneously, may be most readily understood by be-

ing examined separately. These are—1st. the parting with superfluous water by evaporation; 2d. the decomposition of the carbonic acid in the sap by the aid of solar light, the fixation of its carbon, and the disengagement of its oxygen; and 3d. the absorption or inhalation of carbonic acid from the surrounding atmosphere, its decomposition in daylight, and its partial recomposition in darkness. This last process is sometimes called vegetable respiration. All these actions take place in the parenchyma of the leaves, or in the corresponding cellular integument of the stem. From them there results — 1st. the ascension of the sap into the leaves, which we have already considered; 2d. its conversion into the proper nutriment of the plant, and the increase of the latter in weight and size; 3d. the production of the green color of leaves and leaf-like parts; and 4th.—a most important result in the general economy of nature, viz.: the restoration to the atmosphere of the oxygen gas which has been taken from it by the breathing of animals, the decomposition of vegetable matter, combustion, and many other natural and artificial processes.

75. *The evaporation of the superfluous water of the sap principally takes place through the breathing-pores, and its quantity is in direct proportion to the light to which the plant is exposed.*

A slow evaporation through the cuticle is in all probability going on continually from the whole surface, the extent of which depends upon the state of the atmosphere as to dryness or moisture. All the evaporation from leaves which are deprived of a true cuticle, as those of Mosses, is of this kind; but the obvious office of the cuticle is to restrain or wholly prevent this effect, which it especially does when composed of several layers. The leaves of very succulent plants, in which the breathing-pores are closed, may be exposed for several days to direct sunshine, in midsummer, with scarcely any loss of weight.

If we take three similar leafy plants, and, preventing absorption by the roots, place one in direct sunshine, another in ordinary daylight, and the third in darkness, it will be found that the first has lost a large quantity of water, the second a less amount, and the third scarcely any at all. That this loss has taken place through the breathing-pores, seems almost certain, from the fact, that these only open when exposed to light and dryness, their very hygroscopic mouths immediately closing in the absence of light, so as to check further evaporation. The stomata open into the cavernous parenchyma of the lower side of the leaf (51), and the thin membrane of the cellules, being directly exposed to the air, freely parts with its moisture in a state of vapor. This process, therefore, differs in some degree from ordinary evaporation, being controlled by the nature of the cuticle and the state of its breathing-pores: it has been termed *perspiration* or *transpiration*.

The perspiration of leaves, under the most favorable circumstances, is very abundant: some plants lose more than their own weight in every warm and dry day; a young Sun-flower plant has been known to lose more than 20 ounces per day. A cool polished piece of metal or of glass, held near the leaves of a Vine, in a warm bright day, condenses the escaping moisture, and is soon covered with a fine dew.

Young leaves perspire the most copiously; after a time the foreign substances taken in with the sap choke the parenchyma, and the leaves become feeble and finally fall off: on this account, leaves require to be renewed from year to year.

76. *Leaves in the day-time decompose the carbonic acid of the sap, give up the oxygen to the atmosphere, and retain the carbon.*

This is clearly proved by the following experiments instituted by Senebier, which have often been repeated by other observers with the same result. He filled a glass jar with air which contained no oxygen, and placing in it a fresh leafy branch, the base of which was immersed in water charged with carbonic acid, exposed the whole to direct sunshine. As soon as the branch began to wither, it was withdrawn, and fresh ones substituted. After the experiment had been several days continued, he examined the air in the vessel, and found that it contained a portion of oxygen gas equal to the quantity of this substance the branches had absorbed from the carbonated water. The experiment was then varied by placing similar branches in an inverted jar filled with water; the branches were allowed to absorb carbonated water, and were exposed to sunshine as before: the result was similar; a quantity of nearly pure oxygen gas, being disengaged from the leaves, rose to the upper part of the vessel.

By the decomposition of the carbonic acid of the sap, plants accumulate carbon in their tissue, and acquire an increase of solidity. This decomposition also causes the green color of all the organs in which it takes place. The greater the exposure of plants to the light, the more vigorous is their growth and the deeper the green hue of their leafy parts. Plants exposed to full sunshine, therefore, have a deeper tint than those that grow under the shade of trees. If we cause a plant to grow in darkness, the green color will not appear at all, and its tissue will be loose and watery; indeed, it will consist of little else than carbonic acid and water. In our gardens Celery is blanched by covering the stems with earth; the oxygen accumulates, and the green color disappears, and with it the strong odor and the poisonous qualities of the plant. If blanched plants be again exposed to the light, they lose their superfluous water, give out oxygen, and again become green and solid, acquiring at the same time their peculiar taste and odor. Hence it is that in countries where the light of the sun is most powerful,—that is, in equatorial regions,—we meet with plants which have the most intense colors, the strongest odors, and the most active properties. Direct sunshine is not essential to vegetable growth, for many plants thrive in the ordinary light of day. Nevertheless the vigor and rapidity of vegetation is in direct proportion to the intensity of the light.

77. *Leaves, when exposed to the direct light of the sun, also take in carbonic acid from the surrounding atmosphere and exhale oxygen; in the absence of light they inhale oxygen.*

It is probable that leaves take in a quantity of oxygen, and perhaps also part with a little carbonic acid, in daylight as well as in darkness; but during the day this is more than balanced by the inhalation of carbonic acid and the restoration of its oxygen to the air. When freshly-gathered leaves are exposed to direct sunshine under water, they are very soon covered with minute air-bubbles. The earliest observers of this circumstance supposed these bubbles to be liberated from the water by the heat of the sun; for when leaves were placed in water which had been boiled, so as to drive off the air held in solution, no air-bubbles appeared. It came to be observed by those who examined this subject more closely, that these bubbles were not common air, but nearly pure oxygen gas; and moreover, it was found that they were only given off from the surface of living leaves. Three conditions are necessary to this disengagement of oxygen:—1st. the organ must be green and living, since recently killed but still green leaves emit no gas; 2d. exposure to direct sunshine, for neither the clear light of day nor that of the brightest lamps produces any effect; and 3d. there must be carbonic acid in the water. De Candolle contrived a beautiful experiment to prove that the oxygen we collect in such cases arises from the decomposition of this carbonic acid, and is consequently proportionate to the quantity of carbonic acid that is decomposed. He placed in a cistern filled with distilled water, two inverted glass jars, one of which was filled with the water of the cistern, and had floating in it a plant of Mint; the other contained carbonic acid gas. To prevent all absorption of carbonic acid from the air, the surface of the water in the cistern was covered with a thick layer of oil. The whole apparatus, thus arranged, was exposed to sunshine. At first no gas was disengaged from the plant; but as fast as the water rose in the other vessel by the absorption of carbonic acid, it sunk in the one which contained the plant, from the disengagement of an equal volume of oxygen. The experiment was repeated, substituting oxygen gas in the place of carbonic acid; but in this case no gas was given off from the plant.

Submersed aquatic vegetables, such as many Pond-weeds, are placed under similar circumstances. Having no cuticle, they imbibe carbonic acid from the water, and give out oxygen by their whole surface; just as fishes, by their bronchiæ or gills, imbibe oxygen and give out carbonic acid from the same element.

Leaves act on the carbonic acid of the atmosphere in the same manner as upon the same gas dissolved in water: if placed in a jar filled with carbonic acid and common air, the former gas disappears, and an equal bulk of oxygen is left in its place. In leaves protected by a cuticle this decomposition is effected in the cavernous parenchyma of the lower surface, and the air is admitted and expelled through the breathing-pores: this mechanism has been compared to the lungs of animals.

In full sunshine, vigorous plants will thrive in an atmosphere containing 12 per cent. of carbonic acid; yet in the shade, a much smaller quantity of this gas is deleterious. Plants cannot live in an atmosphere deprived of oxygen; its presence seems to be necessary at all times, but in the night especially leaves absorb it from the atmosphere, and, combining with the carbon of the plant, the action of the day seems to be reversed during the night; but the next day this carbonic acid is again decomposed by solar light, and nearly all the oxygen is restored to the air. The object of this alternate absorption and expulsion of oxygen gas is not well understood. This inhalation of oxygen and exhalation of a small quantity of carbonic acid which takes place at the same time, Professor Burnett proposes to term the true respiration of plants, deteriorating the air like that of animals. The decomposition of carbonic acid, which takes place only in daylight, belongs, according to this view, to the process of digestion. The object of the breathing of animals is to get rid of the superabundant carbon; this is effected by its union with the oxygen of the air, which is thereby converted into carbonic acid. On the other hand the ultimate object of vegetable nutrition is just the reverse, viz.: to part with the excess of oxygen, and to appropriate the carbon.

All the parts of a plant which in botanical language are said to be colored (that is, those which are not green, such as flowers, colored fruits, &c.) absorb oxygen from the air at all times, and return to it an equal bulk of carbonic acid, both in darkness and in light.

As to the influence of vegetation upon the atmosphere, it is obvious that plants deteriorate the air by slowly taking away oxygen and restoring carbonic acid, by their colored parts at all times, and by their green parts during the night. On the other hand, they purify the air and render it fit for the breathing of animals, by taking in carbonic acid, fixing the carbon in their tissue, and restoring the oxygen to the atmosphere. It is evident that the latter process very much exceeds the former, since the general result of the phenomena we have described is to increase the quantity of carbon in the plant, and add to its growth; and for each particle of carbon added to the plant, more than twice its weight of oxygen gas is restored to the atmosphere. Thus, while the breathing of animals, by producing carbonic acid, which will not support animal life, vitiates the air, plants purify it again by decomposing this carbonic acid, and restoring the oxygen. Vegetation, therefore, is a provision on a grand scale for maintaining the world in a habitable state.

SECT. V. *Of the descending or elaborated Juice; Secretions, &c.*

78. The sap, having undergone in the parenchyma of the leaves the changes which we have considered in the preceding section, no longer consists of water and carbonic acid, but its elements are now combined in a different manner, so as to form a new fluid immediately adapted for the nourishment and growth of the plant. This fluid is called the *descending* or *elaborated sap* or *juice*. It is carried from the leaves into the bark, descending towards the roots through the cellular and also the fibrous and vascular tissue; it also flows laterally into the stem along the medullary rays.

That this fluid chiefly descends in the bark is proved by the swelling of Exogenous stems just above a tight ligature placed around them. Moreover, if we cut into the bark during the summer, the juice flows out most freely from the upper edge of the wound. The particular route of the descending sap in Endogens is not well determined.

The descending juices are of two kinds. The nature of the one kind is nearly the same in all vegetables, being always bland, and generally containing a great abundance of mucilage or sugary matter: this fluid serves directly for the growth of the plant, and is therefore termed the *nourishing juice*. The other kind of descending juice is the material which forms the special products of vegetables, such as the resinous liquid of the Pine and Fir, the milky juice of the Lettuce and Poppy, &c.: its properties being widely dissimilar in different plants, this fluid has received the name of *proper juice*. The office which the proper juices fulfil in the vegetable economy is but slightly understood. They do not appear to take any direct part in the nourishment or growth of plants.

The nourishing juice is thought to descend chiefly in the liber or fibro-vascular portion of the bark: it is this fluid, and not the ascending sap, which is analogous to the blood of animals. The proper juice is mostly contained in the cellular tissue of the bark, and kept distinct from the nourishing juice; for all the *special products*, when mingled with the ascending sap, are more or less deleterious to vegetable life, even of the plant which produces them.

79. The *nourishing juice*, being formed from the ascending sap by the process of vegetable digestion, essentially consists of the elements of water (oxygen and hydrogen) and carbon. Besides these elements, it sometimes contains a little nitrogen, and minute quantities of the mineral substances taken into the plant with the ascending sap; but the presence of these last is in one sense accidental, they being wholly unessential to the growth and complete development of the plant which contains them. This statement, however, cannot be made of the nitrogen, which is a true element of

several vegetable products. Some mineral substances, moreover, if not essential constituents of the plants in which they occur, are at least turned to good account; as in silex, which gives strength and firmness to the stalks of Grasses, the rind of the Rattan, and of some Palms, which become hard enough to resist the blow of a hatchet. To term the silex in these and similar cases an accidental and foreign body, is certainly unphilosophical and incorrect.

We know little of the precise manner in which the nourishing juice produces new fibres, vessels, or cellules; the principal facts bearing upon this recondite subject are elsewhere stated (7, 12, 41, 42; see also the chapter on Flowerless Plants.).

80. The nourishing juice in its simplest and primitive state is mucilage; a substance which results from the new arrangement of the elements of sap after it has parted with its superfluous water by evaporation, and its carbonic acid has yielded its oxygen to the atmosphere. It is essentially composed, therefore, of water, or its elements, and carbon. By slight changes in its composition, this mucilaginous fluid gives rise to the various products or secretions known to be destined for vegetable nourishment and growth. These products (of which gum, starch, sugar, and lignin are the principal) all consist of the same elements united in nearly the same proportions; they are spontaneously convertible into each other in the living plant, as well as by artificial means; oxygen and hydrogen exist in all of them in the exact proportion to form water; but we know nothing of the manner in which their component elements are united.

These principles are by chemists usually termed neutral vegetable products, because they have neither alkaline nor acid properties: from their composition De Candolle calls them hydro-carbonated bodies; and, on account of their common convertibility into sugar, Prout unites them under the name of saccharine principles.

Of all these nutritive products, *gum*, or rather *mucilage*, which is a solution of gum, is the most common.

It exists in all plants without known exception; it is found in all their organs, above all in the leaves, where it is produced, and in the bark; in many plants it is very abundant, as in the Mallow, the Sassafras, the Linden, the Slippery-Elm, the Cherry, many Acacias, and all the trees called gum-trees. When the bark of the Plum or Cherry-tree is injured, or wounded by the bite of insects, gum exudes copiously. As obtained from the bark of several species of Acacia, it is known by the name of gum arabic. Gum, therefore, being the most general of all the products of this kind, as well as the only one usually produced in the leaves themselves, may be assumed as the type of the nutritious products, and the essential element of elaborated sap. Being formed in the leaves, it descends in the bark quite to the extremities of the roots, a portion finding its way into the stem through the medullary rays, and another portion, known by the name of cambium, being deposited between the wood and bark at particular seasons.

The *jelly* which abounds in the Grape, Gooseberry, and all acid succulent fruits, is mucilage combined with, or modified by the presence of, a vegetable acid.

A portion of the nourishing juice which enters the tissue of the stem mingles with the ascending sap it there encounters, and is carried along with the latter towards the leaves, furnishing the material for the development of buds and all parts that grow in an upward direction.

Another portion is commonly retained in the cellules of some part of the stem, root, or other organ, assuming the form of *fecula* or *starch*. This substance, widely as it seems to differ, is gum slightly modified in some of its properties, being composed of minute grains, each of which has an envelope of a less soluble but otherwise similar matter. It is owing to this envelope that the grains of starch are not affected by cold water, nor mingled with the ascending sap in the tissue of the stem. Hot water converts it into a thick mucilage, and, in larger quantity, dissolves it completely. Dry starch also, when slightly heated, is rendered soluble in cold water, and when this solution is evaporated to dryness, a substance remains, having nearly all the properties of gum. Cold water indeed will slowly convert starch into mucilage, if it be previously reduced to a fine powder, so as to destroy the insoluble envelope of the grains.* Digestion in a weak acid converts starch first into a kind of gum, and then into sugar. A temperature of about 90° Fahr., or the ordinary heat of summer, it is well known, also changes a solution of starch into sugar.

While gum is the ordinary nourishment of plants, starch, like the fat of animals, to which it has been aptly compared, is nutritious matter stored up in such a manner as not to be dissolved in the water of vegetation, being consumed in supporting the plant at particular periods. Thus, it is accumulated in the cotyledons or seed-leaves (174) of Peas and Beans; in this case forming a magazine of food for the support of the rudimentary plant, until it has produced a root, stem, and leaves. In wheat, buck-wheat, Indian corn, and numerous other instances, a quantity of starch, greatly exceeding the embryo-plant in size, is accumulated around it or deposited by its side, being subservient to the same office as in the former case.

In tubers, such as the Artichoke and Potato; in rhizomas, as the Arrow-root plant, the Iris, &c.; in cormi, as in the Arums, Colchicum, &c.; and in biennial or perennial fleshy roots, as the Sweet Potato and Beet, the starchy matter is intended for the nourishment of young shoots. It accumulates in the centre of some Endogenous stems, as in the Sago Palm, in which it is a reservoir of food for the leaves. Starch also is accumulated about the summit of many flower-stalks, where it serves as food for the young flowers.

This substance, whether deposited in roots, stems, fruits, or seeds, is most abundant when the vegetation of the season is finished, at which time it is secured for the sustenance of man and animals; it remains stationary during the winter, or as long as vegetation is suspended, and rapidly diminishes when the organs grow for whose nourishment it was provided. Thus biennial plants, such as the Beet and Turnip, produce scarcely any stem during the first season of their growth, nearly all the nourishing matter they create being deposited in the root; the next year they draw upon this stock of food, rapidly developing stems and flowers, and when the reservoir is exhausted the plant perishes.

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* Berzelius, *Traité de Chimie*, V, p. 199.

For a similar reason, timber felled in winter contains the greatest quantity of solid matter, and is therefore most durable. In the spring when the trunk is gorged with sap, a portion of this solid matter in the form of starch is dissolved, being changed into gum or sugar, and, carried upwards with the sap, contributes to the development of the buds, enabling the plant to flower before the leaves appear; as happens in many forest trees, in some biennial and perennial herbs, but never in annuals.

In the living plant, gum or starch is often changed into sugar. *Sugar*, in some of its forms, exists in the stem of Sugar-cane and of Indian corn, in the root of the Beet, and in the sap of the Sugar-maple. It is probable that starch is always converted into sugar when it is taken again into the circulation of the plant. Sugar seems to be a highly nutritious food, accumulated for the nourishment of flowers and fruit. Thus, in the Sugar-cane it is most abundant just before the time of flowering, rapidly diminishing in quantity during this period. The stem of Indian corn, and also the receptacle of its fertile flowers, is filled during its growth with a sweet liquid, which, being mingled with the ascending sap, serves for the nourishment of the flowers. A portion which is not required for this purpose is deposited in the seed around the germ or rudimentary plant, having again assumed the form of starch. When the seed grows, this store is again converted into sugar for the nourishment of the young plant. So, although chemists can only convert starch into sugar, nature readily effects both transformations.

Lignin, the substance of which the vegetable fibres, cellules, and vessels themselves are formed, results from the final organization of the nourishing juice.

Its composition accordingly is very similar to that of nutritious principles just described, from which it differs chiefly in its insolubility and in having a greater quantity of carbon in its composition. All the other principles of this class finally arrive at the state of lignin. If, as is most probable, this substance is formed from mucilage by the loss of water or its elements, and the consequent increase of carbon, we are enabled to understand why the parts of vegetables which are most exposed to light and air harden most rapidly, and why the timber of trees growing in open places is more durable than that of the same species growing in dense forests.

Lignin, being the most stable of the vegetable products, undergoes no further change in the living plant. Like starch, however, it may be transformed into gum or sugar by the action of chemical agents. The different kinds of wood consist of from ninety to ninety-six per cent. of lignin: it is obtained nearly pure by digesting saw-dust or the cuttings of wood successively in alcohol, water, and dilute muriatic acid, until all soluble matters are taken up. If the substance thus prepared be mixed with a quantity of strong sulphuric acid, it is converted into a mucilaginous, soluble mass, which, when the excess of acid is removed by the proper agents, is found to be nearly pure gum.* The quantity of gum formed in this way is said to be equal in weight to the lignin employed. If the digestion be continued longer and aided by a moderate heat, the mucilage disappears, and a kind of sugar similar to that of grapes is produced. Braconnot, to whom we are indebted for these important discoveries, succeeded in preparing fine sugar from straw, bark, old linen, and other substances which contain much woody fibre. Moreover, Autenrieth, a German chemist, has quite recently shown the practicability of converting lignin into an article of food. Wood, in his process, is reduced to a coarse powder and digested for some time in water to remove all soluble substances; it is then baked, reduced to a fine powder, and made into loaves, a small quantity of flour being added to render it coherent, and again baked; when it becomes according to Autenrieth's account a pleasant and nutritious article of diet, very similar to bread made from Indian corn. Is the lignin simply rendered more soluble, or is it converted into some other principle by this process? Or, as Berzelius* intimates, does the gastric juice cause it to undergo changes analogous to those produced by sulphuric acid?

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* According to Raspail, who supposes lignin to consist of gum combined with a saline or calcareous base, sulphuric acid reconverts this substance into gum merely by uniting with this earthy base.—See *Nouveau système de Chimie Organique*, p. 313.

81. It was stated in the preceding section that the green color of the leaves and leaf-like parts of plants results from the decomposition of carbonic acid and the disengagement of oxygen. The matter to which this color is owing has received the name of *Chromule* (5). It consists of minute grains of green matter adhering to the inside of the cellules of the parenchyma where it originates; it has not been ascertained whether it results from the nutritive or proper juices of the plant. This substance in its different states is the general coloring matter of leaves and all leaf-like organs; being usually green in leaves, except they languish from disease and give off oxygen sparingly, when the chromule assumes some shade of yellow or red. The change of color is supposed to be owing to the action of oxygen upon the chromule. These changes are very striking in our forest-trees during the frosts of autumn. Some leaves are colored while in a healthy state, by the oxydation of the chromule from some unknown cause: of this kind are the deep-red floral leaves of Castilleja coccinea,† and of some species of the Sage. Leaves are blanched when excluded from the light, their chromule being decomposed by the abstraction of carbon.

The colors of flowers are also supposed to depend upon modifications of the chromule, an accumulation of oxygen producing red, with all its shades, and an excess of carbon giving rise to blue, yellow, and all the tints of that series of colors.

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* p. 126. † Euchroma, *Nutt.*

82. Little is known concerning the office of the *proper juices* in the economy of plants. They consist, like most other vegetable products, of carbon, hydrogen and oxygen, but the two latter elements are not present in the exact proportions to form water; sometimes the oxygen, but more frequently the hydrogen, is in excess: some proper juices also contain nitrogen.

Proper juices are of two kinds, viz.: those which naturally find their way out of the plant, and those which are formed and stored up in its interior. The substances destined to be thrown out from the surface of the plant are termed *excretions.* They are usually formed in a little apparatus called a gland (18), but often no peculiar contrivance for their production can be perceived. Some glands excrete an aromatic substance, usually a volatile oil, which gives the plant its peculiar odor. The stems and flower-stalks of the Fraxinella of gardens, particularly the red-flowered species, are covered with little glands which excrete a volatile oil, giving the plant its powerful balsamic odor. This excretion is so abundant that at the close of a warm and dry day in summer it will take fire by the application of a lighted taper, producing a bright flash which does no injury to the plant.

Glutinous excretions are produced by the stalked glands of the fruit and young branches of the Butternut, the flower-stalks and calyx of Rubus odoratus, and the little glands mounted on the tips of the stout hairs of the Drosera or Sundew. A similar glutinous matter covers the branches of the Clammy Locust (***Robinia viscosa***), and also the scales of many buds. (***Ex.*** Æsculus, Populus.) Those glands furnished with hollow bristles or stings through which the juice exudes, contain an acrid and poisonous liquid which flows out through the sting when the gland is pressed upon: the stings of the Nettle (*fig.* 15, *c.*) are of this kind. Acid excretions are not uncommon. The berries of the common and the smooth Sumach (***Rhus typhina*** and ***glabra***) are covered with a very sour excretion which has been proved to be malic acid: the leaves of Uralepis aristulata, a common grass of the sea-coast, also produce drops of a sour liquid.

To protect them against the effects of moisture, the surface of some plants is covered with a wax-like powdery efflorescence, which gives them a *glaucous* appearance, as is seen on the leaves of the Cabbage or Raspberry, and the fruit of the Plum, where the true color is masked by this whitish powder. The fruit of the Bayberry (*Myrica cerifera*) is furnished with a thick layer of vegetable wax, which may be collected in large quantities by throwing the fruit into boiling water, when the wax melts and rises to the surface; it is used for making candles and for other purposes, and is popularly supposed to possess medicinal virtues. Some aquatic plants have a thick covering of clear mucilage, which protects them from the undue action of water. Every part of the Water-shield (*Hydropeltis purpurea*), which abounds in the shallow water of lakes and ponds, is covered with a thick and transparent jelly, except the upper surface of the leaves which are exposed to the air.

The excretions which are deposited in the soil by the roots have been noticed in another place (25). By these excretions principally, vegetables are enabled to rid themselves of the useless or noxious substances continually taken in with the ascending sap.

83. Those proper juices which are formed and retained in the interior of the vegetable, and do not naturally find their way to the surface, are termed *true proper juices* or *secretions.*

These fluids are not common to all plants, but are confined to particular species or to special organs. They are likewise kept in closed vessels or cellules, so that they are not liable to mingle either with the nourishing juice or ascending sap. Their office in the vegetable economy is a matter of conjecture; they do not contribute to the process of nutrition, since they act as poisons when absorbed by the roots of living plants, even of those which have produced them. The composition of these fluids is more complex than that of the nourishing products; they are not mutually convertible into each other; they usually contain a greater proportion of carbon; and they nearly all consist of two or more distinct principles which may be readily separated. They require for their formation considerable heat and a full supply of light; so they are seldom formed in the shade, and always attain the greatest perfection in tropical climates.

We may arrange them under the heads of milky juices, resinous juices, volatile oils, and fixed oils.

1. *Milky juice,* when met with in any tribe of plants, may be expected to occur in every species of the family; but there a few exceptions to this rule. It is found in all the Asclepiadeæ or Milk-weed tribe, in all the Poppy tribe, and in that section of Compositæ which comprises the Lettuce.

Milky juice is usually white, yet it is orange in Celandine (*Chelidonium majus*) and the Gamboge-tree, and pale red in the Sanguinaria or Blood-root. These fluids are principally contained in the bark, commonly of the stem, but sometimes of the root also, and when this is wounded they flow out copiously from both sides of the incision.

This juice consists of fine particles of resinous and other matters half-dissolved, or rather suspended, in a mucilaginous fluid; it usually exists in such a state of concentration that the juice soon solidifies on flowing out of the plant, forming the class of substances known by the name of gum-resins. They comprehend several substances highly valuable both in medicine and the useful arts. Thus, *opium* is the concrete milky juice of the Poppy, and that of the Lettuce is very similar in its properties; *gum ammoniac, galbanum,* and *assafœtida* are yielded by as many species of umbelliferous plants; *aloes* is furnished by several species of the Aloë, *scammony* by a species of Convolvulus; and the famous Cow-tree of South America, which yields a copious supply of a wholesome and nourishing milk, belongs to the Bread-fruit tribe (*Artocarpeæ*), which abounds in milky juice. The *Upas* of Java, the most deadly poison in the world, is supposed to be furnished by a tree of the latter family.

Some kinds of milky fluid contain a large quantity of opium, and are therefore termed narcotic milky juices, as in the Poppy, Lettuce, &c. ; in which the soporific qualities are due to the presence of one or more vegetable alkaline principles. Others abound in *Caoutchouc* or India rubber: this is contained in the juice of the Milk-weed and all Asclepiadeous and Apocyneous plants, especially in tropical climates; an elevated temperature and strong light being requisite to the abundant production of this substance. The East India caoutchouc is the product of Urceola elastica and several other Apocyneous plants, and also of Ficus elastica, which belongs to the Bread-fruit tribe. The American caoutchouc is chiefly obtained from several Euphorbiaceous trees.

Milky plants are almost always acrid or poisonous: the acridity, however, is sometimes dissipated by heat, or the noxious juice may often be extracted from the organ that contains it by strong pressure, leaving the nutritious starchy matter in a wholesome state; as the Cassava-flour or tapioca, so extensively employed in place of bread in South America and the West Indies. This substance is prepared from the roots of Janipha Manihot (*Jatropha*, Linn.), an Euphorbiaceous plant, its virulent juice being extracted in the manner just mentioned. Noxious plants of this kind are often wholesome when quite young, before they have had time to elaborate milky juice. Thus, the early leaves of the Lettuce are used as a salad ; and the young vernal shoots of the common Milk-weed (*Asclepias Syriaca*) are often employed as a substitute for Asparagus. As the milky juice descends in the cellular integument, the wood and the fruit of such plants may be harmless, while the bark of the stem or root is highly poisonous.

2. *Resinous juices*, consisting of resin dissolved in an essential oil, abound in several orders of plants, especially in the Coniferæ or Fir tribe. They are in the trees of this family deposited in the intercellular passages of the bark and wood, where by their weight they form irregular cavities or cysts often of very conside-

rable size. The juice, as it exudes from the wounded trunk of Pines or Firs, is called *turpentine*. Its properties vary, and it is known under different names as obtained from different species. All these juices consist of one or more resins and an essential oil, called *oil of turpentine*, which may be separated by distillation. The common European Larch yields *Venetian turpentine: Canadian balsam*, which has a fragrant and agreeable odor when warmed, is yielded by the Balsam-Fir (*Abies balsamea*).

The true *balsams* are natural compounds of resin and benzoic acid, flowing from incisions made in the trees which contain them in the same manner as turpentine from the Pine. Some remain liquid,* as the balsam of Tolu; a few, such as *benzoin*, are solid.

3. *Volatile oils*. Volatile or essential oils are met with in nearly all odoriferous plants, giving them by their volatility their peculiar odor. They are found only in the foliaceous or cortical system of plants, in some of which, such as the Thyme, Mint, and other Labiate plants, the same kind of oil is dispersed throughout their stems, leaves and flowers. In other plants the leaves, flowers, or fruits alone contain volatile oil. Thus the peculiar aroma and flavor of the fruits (commonly called seeds) of Umbelliferous plants, such as the Caraway, Coriander, Anise, &c., are owing to the presence of several oblong bags or reservoirs of volatile oil in their rinds. The peculiar oil of the Rose (called *otto* or *attar of roses*) exists in the flowers only. Sometimes different parts of the same plant contain different kinds of volatile oil. Thus the Orange furnishes three kinds of volatile oil, one of which resides in the leaves, another in the flowers, and a third is confined to the rind of the fruit.

Volatile oils are generally produced and stored up in little receptacles or vesicular glands (13, *fig.* 11.)

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* The resinous juice of the Sweet-Gum tree (*Liquidambar stryraciflua*) is by some authors said to be a balsam. See Berzelius, *Traité de Chim.* V., p. 464. It is, however, rather a sort of turpentine; Prof. Torrey having ascertained that it contains no benzoic acid.

which are evident to the naked eye in the leaves and petals (114) of the Orange and Lemon, and also in the rind of the fruit. These little cells, being more translucent than the other portions of the leaves or petals, give the latter, when held against the light, the appearance of being punctured with numerous fine holes: hence these are said in botanical language to be *pellucid-punctate.* Some Hypericums exhibit transparent dots; in other species these are opaque and dark-colored, being filled with a colored liquid. We are wholly ignorant of the use of volatile oils in the vegetable economy. They are composed of two principles intimately combined but capable of being separated by artificial means, viz.: a highly odorous and fluid portion called *elaiodine*, and a crystalline or concrete, sometimes inodorous, substance termed *stearoptine.* The latter element in many essential oils (especially of Labiate plants) very much resembles camphor; and De Candolle suggests that true camphor is the stearoptine of the essential oils of the Laurels, &c., which yield this substance destitute of elaiodine.

4. *Fixed oils* are usually met with in seeds; in the Olive tribe alone it abounds in the fruit. Of all seeds those of Cruciferous plants are most rich in fixed oil, some of them yielding from one to two thirds their weight of this product. Next to these we may rank the seeds of the Butternut, the Beech, &c. among Amentaceæ; among Leguminous plants those of the Pea-nut, Cotton, &c.; and among Rosaceous plants, the Almond. In all these cases the oil is contained in the cotyledons (174). In the seed of the Poppy, which yields about one third its weight of oil, and that of the Castor-oil plant, (*Ricinus communis*), the oil is contained in the albumen (173).

Fixed oils are almost wholly composed of two elements only, viz.: hydrogen and carbon. That they are not simple vegetable principles, chemists have long known: they consist of a fluid substance called *oleine*, or *elaïne*, and another principle which is solid at ordinary temperatures, resembling suet, and therefore termed *stearine.* We shall not pursue further the chemical or the natural history of the fixed oils; for, although extensively useful in the arts, they do not especially interest the botanist.

Volatile oils are generally obtained by distillation,—fixed oils by pressure. During the germination of the seed, the latter are supposed to be changed into mucilage, and accordingly to contribute to the nourishment of the young plant.

We have very briefly noticed the principal secretions with which the botanist is interested, being those that appear to play the most important part in the vegetable economy. There yet remains another class of products, which have, so far as we know, little connection with vegetable nutrition, and though found indifferently in the various parts of a plant, have no special organs for their production or reception. These principles are very numerous, although we are probably acquainted with but a small part of the true number furnished by the vegetable kingdom. They may be arranged under the heads of acids, alkalies, neutral principles, resin-like principles, and coloring principles.

The consideration of the nature and properties of these products is the province of vegetable chemistry. Even their enumeration would exceed our limits; for almost every plant that has been examined for this purpose, is found to present one or more peculiar principles. We subjoin, therefore, a mere catalogue of the most important and best known principles of this class, under the sections just indicated.

I. ACIDS.

Oxalic	acid	exists in	Sorrel and many Lichens.
Malic	"	"	apples, gooseberries, &c.
Citric	"	"	lemons, the cranberry, &c.
Tartaric	"	"	grapes. This acid and the two preceding are converted into sugar during the ripening of fruits, and might therefore have been ranked with the nutritive products.
Acetic	"	"	the sap of many plants,

Meconic acid exists in opium.
Tannic " " the bark of trees.
Gallic " " gall-nuts and the bark of trees.
Kinic " " the bark of Cinchonaceous plants.
Benzoic " " Balsams and sweet-scented Grass.
Hydrocyanic (Prussic) " the Peach, Cherry, Almond, &c.

II. ALKALIES.[†]

Morphia, Narcotina exist in the milky juice of the Poppy.
Sanguinarina exists in Sanguinaria or Blood-root.
Strychnia " the juice of Apocyneæ.
Quinia, Cinchonia " Peruvian bark, and that of other Cinchonaceous plants.
Veratria " Veratrum, Colchicum, &c.
Nicotia " Tobacco.
Picrotoxia " Coculus Indicus.
Solania " the berries and stems of several species of Solanum.

III. NEUTRAL PRINCIPLES.

Gluten exists in the grain of Wheat, Rye, Barley, &c.
Asparagine " the stems of Asparagus and Liquorice.
Bassorine " Salep, the roots of Orchideæ, &c.
Caffeine " Coffee.

IV. RESIN-LIKE PRINCIPLES.

Elaterine, or Elatin exists in the fruit of Momordica Elaterium and other Cucurbitaceous plants.
Jalapine exists in the Jalap and other Convolvulaceous plants.
Abietine " Coniferæ.
Gentianine " the Gentian.

This section is not well distinguished from the preceding.

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[*] Anthoxanthum odoratum and Hierochloa fragrans.

[†] The vegetable alkalies are all composed of four elements, viz.: oxygen, hydrogen, carbon, and nitrogen.

V. COLORING PRINCIPLES.

Hæmatine	is the coloring principle	of logwood.
Bresiline	" "	of Brazil wood.
Indigotine	exists in	all the species of Indigofera, in Woad, and many other plants of different families.
Polychroite	"	the Saffron (*Crocus sativus*).
Alizarine	"	the Madder-plant.
Chromule	"	the general coloring matter of leaves and flowers (81).

SECT. VI. *Of the special Directions and sensible Movements of the Organs of Plants.*

84. The uniformity in the directions taken by the several organs of plants, is one of the most remarkable yet least observed phenomena of vegetable life. Persons unaccustomed to reflect upon occurrences familiarized by daily observation, hardly conceive that there is anything wonderful or mysterious in the perpendicularity of stems, the downward growth of roots, and the turning of leaves and branches towards the light. The attention of vegetable physiologists, however, has often been directed to these circumstances; but their immediate causes have not in all cases been very clearly made out.

The tendency of the root to descend and of the stem to rise in the contrary direction, is strongest in a young plant just growing from the seed; being then invariable, whatever may be the position of the seed and the nature of the surrounding medium. It is well known, that when a seed is placed in the ground in an inverted position, the radicle or rudimentary root makes a turn to bury itself in the earth; and if the plant be a second time inverted shortly afterwards, both the young root and stem again turn, each assuming its original direction. The law of gravitation offers a ready explanation for the descent of the root; the greatest difficulty being to account for the ascension of the stem in direct opposition to the force of gravity.

As light exerts a marked influence over the growth of stems, and not upon roots, which on the contrary grow most rapidly in darkness and humidity, it might be supposed that the latter descend or remain in the soil because they are attracted by moisture, and that the former rise into the air by the influence of light. To test the truth of this supposition, Dutrochet filled a box with moist earth, the bottom being pierced with many holes, in which he placed seeds of the kidney-bean; the box was then suspended in the air about 18 feet from the ground. The seeds being thus situated, it should follow if the young stem is attracted by the light and the root by moisture, that the former should shoot downwards into the air, and the roots upwards into the moist earth. This, however, did not take place, but on the contrary the radicles descended into the atmosphere, where they soon dried up and perished; and the stems ascended vertically, forcing themselves into the earth. He placed some of the little plants so that the root pointed directly upwards into the soil, but instead of fixing themselves therein, their points turned round and grew in the opposite direction. He accumulated a very large mass of earth above the seeds, but the result was the same as before; proving that the stem is not attracted by air or light, neither is the radicle repelled by light or attracted by moisture.*

That the radicle is not at all attracted by humidity, was more directly proved by Dutrochet in another experiment. He suspended in a bottle a small cup filled with water, containing also a piece of sponge so placed as to present a flat vertical surface. He then suspended within the bottle, by a slender wire, a germinating bean, bringing the radicle as near as possible to the vertical face of the sponge without touching it. In this case, if any affinity existed between the root and the moisture of the sponge, a slight turn of the apex of the former would have brought them into contact. The radicle, however, grew perpendicularly, manifesting no tendency to turn towards the sponge. The damp atmosphere furnished moisture sufficient for the production of many lateral rootlets, of which those arising from the side next to it penetrated the sponge; whereas the other rootlets, though very close to the moistened sponge, showed no tendency to approach it.

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* Dutrochet, *Recherch. sur la struct. intime des animaux et vég., et sur leur motilité* (1824), p. 95.

Mr. Knight, repeating in an improved form an experiment devised by John Hunter, was the first to suggest the true explanation of the vertical growth of stems and roots, viz.: the force of gravitation and the peculiar mode of development of these two organs. Mr. Knight proceeded to test the theory he had conceived, by abstracting germinating seeds from the influence of gravitation, at the same time submitting them to another power which acts in a similar manner. He constructed a water-wheel, upon the circumference of which a quantity of moss was fastened. In this moss seeds of the garden bean were placed, and by means of a stream of water, which served also to moisten the seeds, the apparatus was made to revolve vertically at the rate of 150 times in a minute. In this rapid revolution the seeds were subjected to the centrifugal force alone, which acts like the power of gravitation, but in the opposite direction. After some days the wheel was stopped, and on examining the growing seeds it was found that, in obedience to this force, the stem and root of each rudimentary plant had taken the direction of the axis of rotation, the root being turned towards the circumference and the stem towards the centre of the wheel. This interesting experiment was varied by causing a similar wheel to revolve horizontally; and the result was, that when the wheel revolved with moderate velocity, the roots were directed obliquely downwards and outwards and the stems obliquely upwards and inwards, in obedience to the centrifugal force and the power of gravitation, acting in this instance at right angles to each other. The more rapid the revolution of the horizontal wheel, the nearer do the roots and stems approach that direction; but when the wheel is made to revolve slowly, the force of gravitation preponderates, and the young plant grows nearly in a vertical direction. These experiments were repeated by Dutrochet with a more complicated apparatus moved by clock-work, and always with similar results.

These experiments appear to demonstrate that gravitation is the cause of the vertical direction of the root and stem, in the commencement of their growth. But how is it that the same force acting constantly in one direction causes the stems to rise, whilst the roots descend? The answer to this question, Mr. Knight thinks, is to be found in the difference of the mode of elongation in the two organs, viz.; roots lengthen by addition of new matter in a soft or half-fluid state to their distant extremity only, and they therefore descend simply by the force of gravitation: young stems on the contrary grow by the increase of parts already formed, the elongation taking place throughout their whole length; they accordingly from their first development have a disposition to take the opposite direction. This perpendicularity is continued by a necessary consequence of the growth of stems. If from any cause the young shoot acquires an obliquity while yet beneath the surface of the soil, the juices accumulate on the lower side, which therefore tends to elongate fastest, and thus restores the erect position.

If this explanation of the perpendicularity of stems be true, it follows that when in a germinating seed the roots happen to point directly upwards, and the stem directly downwards, the plant should grow in this direction, although, being in a state of unstable equilibrium, the slightest deviation from a vertical line would cause its inversion. An instance of this kind is mentioned by De Candolle. In further confirmation of this view he also caused the flower-stalk of a Hyacinth to shoot vertically downward under water, and to produce its flowers in this direction.

Some parasitic plants, such as the Misletoe, furnish only real exceptions to this rule; these strike ots into the stems of other plants, and always grow at right angles with the stem to which they are fixed, obeying the attraction of the body on which they grow, rather than that of the earth. The nature of the body does not affect the result in the case of the Misletoe; since even if the seeds be made to germinate on the surface of a cannon ball, the roots will all be turned towards its centre.*

85. The young stem having emerged from the soil, becomes subject to the action of another power, viz. light, which exerts an important influence upon its future direction. It is well known that a plant, placed in an apartment lighted from a single aperture, constantly deviates from the perpendicular position by turning its stem and branches towards the opening through which the light is admitted.

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* This attraction, however, is influenced by the mass of the body; for when Dutrochet caused a seed of Misletoe to germinate on a slender thread, the radicle showed no tendency to fix itself to that substance. He made another interesting experiment which deserves to be recounted here. " I glued," says Dutrochet, " a germinating seed of the Misletoe to one end of a delicate copper needle mounted upon a pivot, a little ball of wax being placed as a counterpoise at the opposite extremity. I then placed by the side of the needle thus prepared, a small block of wood at the distance of about a millémetre (nearly half a line) from the radicle. The apparatus was next covered with a glass shade, so that no external cause could influence the needle. In five days the embryo-plant began to bend, and to direct its radicle towards the piece of wood, the needle not changing its position, although it was extremely moveable. In two days more the radicle was directed perpendicularly to the block, the point being in contact with it, and yet the needle had not moved in the slightest degree."—See Dutrochet, op. cit., *sur Motilité des végétaux*, p. 105.

An account of the several precautions necessary to insure perfect accuracy in this experiment is given in the work from which the above passage is translated. From this and analogous experiments, Dutrochet infers that attraction, as acting upon inert bodies, is not the *immediate* cause of the special direction of the radicle, since in the preceding experiment, an exterior force capable of producing this inflexion would much more readily have changed the direction of the needle; but that attraction is the " cause médiate ou occasionelle " of the phenomenon; the movement being due to an inherent power of the plant, put in action by an external agent. He further concludes, " que les mouvements visibles des végétaux sont tous des mouvements *spontanés*, exécutés à l'occasion de l'influence d'un agent extérieur, et non des mouvements *imprimés* par cet agent."—*loc. cit.* p. 107.

The same tendency exists in the open air, where light being equally diffused around stems is a powerful cause of their perpendicular growth. Light also insures the spreading of branches, which are uniformly so disposed as to have the greatest possible exposure to its influence. Thus, the uppermost branches of a tree are nearly erect; the lower ones extend somewhat horizontally until they reach beyond the shade of the uppermost, and then curve upwards. If the foliage be quite dense, the lowermost branches are turned downwards at their origin from the stem. All their subdivisions also diverge from each other at their origin, and finally turn upwards, unless (as in the Weeping Willow) they are too slender to support their own weight. When a tree is trained against a wall, its young branches manifest a strong tendency to turn in an opposite direction, towards the light.

These phenomena have been considered as the result of vital action, and therefore incapable of further explanation; but all the facts here noticed chiefly result from the operation of a single cause, acting in a simple manner, viz.: the property which light possesses of fixing carbon in the tissue of green parts (76). That side of a stem or branch which has the greatest exposure to light decomposes most carbonic acid, fixes the largest quantity of carbon in its tissue, and consequently solidifies soonest; on the other hand the shady side, which accumulates a smaller quantity of carbon, solidifies more slowly, and accordingly has the power of lengthening in a superior degree. The unavoidable consequence of this is, that the stem or branch curves round towards the side which soonest solidifies and loses the power of elongation, or in other words, towards the strongest light.

This effect is only observed in the green parts of plants, in which alone light has the power of fixing carbon by the decomposition of carbonic acid. When the green color of branches disappears, their direction is no longer influenced by light. Roots, which do not ecome green in sunshine (as is seen in those growing bnwater), exhibit consequently no disposition to ascend when exposed to light and air

Some stems creep underground (29) beyond the reach of light, and accordingly have the white color and much the appearance of roots, showing little upward tendency so long as they remain in this situation; but whenever exposed to the light they first acquire a green hue and then exhibit the same upward tendency as other stems. Hence it is inferred that stems do not ascend merely because they are stems, but because they are colored green by solar light, and that roots do not ascend because they are incapable of acquiring a green color. Dutrochet, in causing some seeds of Mirabilis Jalapa to germinate in damp moss, observed that *the tips of the roots had a slight tint of green*; he was thus furnished with the means of testing the foregoing view, and on exposing them to a beam of light found in the course of a few hours, that all the roots with green tips were pointing towards the place from which the light proceeded. No change in the direction of colorless roots could be produced by these means. The exposed stems of several plants are well known to emit aerial roots, which sometimes acquire a pale-green color, and when this happens they may be made to grow in an upward direction; but when colorless they invariably point downwards.

No satisfactory explanation has yet been offered concerning the twining of voluble stems, or the coiling of tendrils.

86. The upper surface of leaves is always presented to the sky, and the lower to the earth; if this position be artificially reversed, the petioles twist so that the leaves recover their usual direction, or if this be prevented they soon perish. There is always a difference in the structure of the two surfaces of a leaf, as is shown in *fig*. 37., and on account of the nature of this diversity the upper surface is more deeply colored. This is supposed to explain the cause of the upper surface turning to the sky or light. When both surfaces are colored alike, the leaf is usually erect, as in the Iris, the Flag, and many Grasses; and when the lower surface has the deepest hue (which is the case in some Grasses), the leaf twists so as to present that surface to the light.

According to Dutrochet, the same law influences the directions of petals, the most highly-colored surface being presented to the light. Thus in the Pea, the inside of the standard and of the wings (118) is most deeply colored, and accordingly the standard is folded back and the wings or side petals are partly twisted, so as to present the higher-colored surface to the light. There are, however, some seeming exceptions to this rule.

87. The leaves of many plants change their direction in the absence of light. The apparent drooping or folding together of leaves during the night, as if in repose, was termed by Linnæus, in his usual poetical style, the *sleep of plants*. This phenomenon is best observed in the pinnated leaves of the Leguminosæ or Pea tribe. Soon after sunset the leaflets of the common Locust (*Robinia Pseudacacia*) turn downwards as if drooping; they keep this position until morning, when they reassume their horizontal position. Those of many Cassias droop in dull or cloudy weather as well as in the light, being awake only in bright sunshine. It should be remarked, however, that their articulations are not relaxed and flaccid, drooping by their weight during sleep, if sleep it may be called; on the contrary, they are even more firmly fixed in this than in their ordinary position. The nocturnal position of leaves is also uniform in each species. Thus in the common Locust, the leaflets turn downwards on the petiole, bringing the lower surfaces of each pair nearly in contact; while the Mimosas and several species of Cassia have their leaflets directed towards the apex of the petiole, bringing the lower side of each leaflet in contact with the upper face of the one below it. On the other hand, the leaflets of Bladder Senna (*Colutea arborescens*) and of Cassia Marilandica turn upwards at their articulation with the common petiole, so as to place the superior surface of each pair in contact. The sleep of leaves is not confined to the Pea tribe; it is seen in the trifoliolate leaves of the Wood-sorrel (*Oxalis*), and in several plants with simple leaves, as in the Balsam or Touch-me-not, in which the leaves hang

downwards so as to protect the flowers against rain or dews.

We know very little respecting the cause of this phenomenon. Light is the agent which chiefly controls the direction of leaves, the temperature or degree of humidity of the atmosphere exerting little or no effect. This movement, indeed, is known to take place under water as readily as in the open air. De Candolle placed several species of Mimosa, &c., in a cavern, keeping them in darkness during the day, and illuminating them by strong lamp-light in the night. He found that for the most part they change their habits after a little time, expanding when illuminated, and sleeping in the day-time. Several plants, however, were not at all affected by this treatment, but continued, whether in darkness or light, to expand or close their leaves at the same hours with similar plants growing in the open air.

The seat of all these movements is in the articulation connecting the leaf with the stem, or the leaflets with the leaf-stalk; and what is highly remarkable is that light seems in these instances to act upon the joint itself and not upon the lamina, since these movements are similarly executed when a great part of the lamina is cut off.

Although not strictly in place, we may here observe that many flowers close in the absence of light, expanding again in sunshine, in the same manner as leaves. Most of the Cistineæ or Rock-roses expand their flowers in the morning and close them towards evening never to be opened again. On the other hand several flowers, such as the Evening Primrose, Silene noctiflora, &c., expand in the evening and close with the rising of the sun. Each species seems to require light of a particular intensity to expand its blossoms. Thus, the Morning-glory (*Convolvulus Sepium*) opens its flowers at the dawn of day; the Cichoraceous plants, such as Lettuce, a few hours later; the Star-of-Bethlehem (*Ornithogalum umbellatum*) about midday; the Four-o'clock plant at 4 P.M.; and the Evening Primrose, the purple-flowered Convolvulus, &c.,

sometime after night-fall. The successive expansion of many flowers is so regular that the hours of the day are thus indicated with considerable exactness. To show this, Linnæus ingeniously constructed a table, called the Horologue of Flora, in which every hour of the day was indicated by the expansion of some flower.

88. The movements adverted to in the preceding paragraphs are all executed so slowly that they are only perceptible by their results. It still remains to notice those more striking but equally inexplicable movements, which appear to depend for their production upon a high degree of excitability. The movements of the plants called *sensitives* are of this kind Nearly all the species of Mimosa are slightly sensitive, but none more so than the well-known Sensitive plant.* The pinnated leaves of this plant shrink from the hand when touched, rapidly folding their leaflets as in a state of sleep. A slight shock upon one leaflet causes them all to fold themselves one after the other, and at length the impulse reaches the base of the leaf-stalk which immediately falls downwards. After a short interval of repose the leaf-stalk rises again, and the leaflets reassume their ordinary position. These movements are performed both in darkness and light, and in water as well as in air. They are also produced by the light of the sun concentrated by a burning-glass, or by a drop of any irritating fluid, such as sulphuric or nitric acid.

The seat of motion in the Sensitive plant is in the little swelling at the articulation of the general and partial leaf-stalks, but of its cause no very satisfactory explanation has yet been given.

Another curious instance of vegetable irritability is seen in the Dionæa muscipula or Venus' fly-trap, a highly interesting plant which grows in the sandy bogs of North and South Carolina. Its leaves are composed of a roundish lamina connected by a joint with the summit of a dilated leaf-like petiole (*fig.* 55.). The margin of the lamina is fringed with a row of bristles or stout hairs, three or four shorter and more slender ones being placed upon its upper surface. Whenever an insect traversing this portion of the leaf, brushes against these slender hairs, in which the sensitiveness chiefly resides, the two sides of the lamina suddenly come into contact, the bristles of the fringe interlacing like the fingers of the two hands clasped together, so as to imprison the unfortunate insect, whose only chance of escape consists in remaining perfectly quiet until the leaf uncloses.*

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* Mimosa pudica, *Linn.*, and not, as is often supposed, M. sensitiva, which is a large shrub much less sensitive than M. pudica. The name *Mimosa* is derived from *μιμος*, a *mimic*.

The long hairs which cover the leaves of the Sundew (*Drosera rotundifolia*, &c.) are said to be sensitive and to fall when touched at their base with a sharp point, but I have not been able to detect this movement in the American plant.†

The stamens (123) of the Barberry are jointed with the base of the flower, and are so excitable that they fall towards the pistil (134) with a jerk whenever the inside of the filament is brushed by an insect or touched with a bit of stick. The object of this movement is more obvious than in the foregoing examples. It is clearly a provision for insuring the fertilization of the ovary, and will therefore be adverted to in a subsequent chapter.

89. There are a few instances of apparently spontaneous movements among plants. The leaves of Desmodium gyrans, an East Indian plant, furnish the most striking and best-known instance of this kind. The leaf consists of three leaflets: the terminal one, which is largest, does not move except to sleep; but the lateral ones are in continual motion day and night, and even when the terminal leaflet is asleep. They

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* The Rev. Mr. M. A. Curtis, an active botanist, who is familiarly acquainted with this plant in its native situations, has recently published an interesting account of its singular economy. See *Bost. Jour. Nat. Hist.* I., p. 123. (1835).

* In Mirbel, *Elém. Phys. Vég. et Bot.* I., p. 168, it is stated that the leaves of the European Drosera rotundifolia close when touched "comme des bourses à jetons!"

move like the second-hand of a time-keeper, by a succession of little jerks, the one rising while the other falls. The rapidity of the motion is affected by the temperature of the air and by the health and vigor of the plant. In India it is said that they perform, with considerable uniformity, about sixty movements in a minute.

90. Those who maintain that plants are provided with a nervous system analogous to that of animals, but feeble in degree, derive several arguments in favor of this view from the researches of Marcet, Macaire, and others concerning the action of poisons upon vegetables. To ascertain the effects of the different poisons upon the irritability of plants, experiments were made with the Sensitive plant and the Barberry.

"When a leaf of the Sensitive plant is cut and allowed to fall upon pure water, the leaflets contract by the shock, but after a few moments expand again, and are then capable of contraction by the touch of any other body. They may thus be preserved in a sensible state for two or three days. But when a cut leaf of this plant falls upon a solution of corrosive sublimate, the leaf rapidly contracts, the leaflets curl up in an unusual manner, and do not afterwards expand. When put into pure water the sensibility does not again return, but the whole remains stiff and immoveable. A little solution of corrosive sublimate being put into a portion of pure water containing an expanded branch of the plant, gradually caused the curling up of the leaves, which then closed and fell. If the solution be very weak, the leaves open on the morrow and are still sensible, but finally contract, twist, and remain stiff till they die. A solution of arsenic produces the same effect.

"When a leaf was allowed to fall upon water holding opium in solution, it opened as in pure water, and after a half an hour gave the usual signs of contractility. In six hours it was expanded and had a natural appearance, but could not be excited to move. The leaflets were flexible at the articulations, and offered a singular contrast to the state of irritation produced by the corrosive sublimate. Pure water did not recover the plant. A large branch, similarly situated, expanded its leaves, but in half an hour had lost much of its sensibility: the leaflets, although alive, seemed asleep and required much stimulating to cause contraction. In one hour the contractions ceased; in two hours the branch was dead.

"A leaf placed in prussic acid (Scheele's strength) contracted, then slightly dilated, but was quite insensible and the articulations were flexible. If the acid be very weak the leaflets dilate and appear to live, but are insensible. A drop of the acid placed on two leaflets of a healthy plant gradually causes contraction of the other leaflets, pair by pair. After some time they dilate, but are insensible to external irritation; the sensibility returns in about half an hour, but the leaflets appear as if benumbed."*

In the same series of experiments flowering branches of the Barberry were placed, some in a solution of arsenic, others in diluted prussic acid or a weak solution of opium. In each case the stamens soon lost the power of contracting by the touch of a foreign body, but with this notable difference, that in the branches poisoned with arsenic the stamens were stiffly drawn backwards and immoveable, whereas in the other instances they were relaxed and flexible. Moreover, if young plants be watered with weak solutions of arsenic, corrosive sublimate, or any of the acrid poisons, their leaves, beginning with the lowermost, turn yellow and soon die, being killed by the corrosive powers of the poison carried into their tissue. But when similar plants are watered with a solution of opium, they perish in a different manner: in a few hours the leaves droop without losing their natural appearance, and the whole plant dies at once.

All these experiments go to prove that the acrid and narcotic poisons act upon plants much in the same manner as upon animals; that those of the first class, such as arsenic and all the metallic poisons, destroy life by irritation and corrosion; those of the second, by attacking it in some incomprehensible manner throughout the whole plant at once.

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* Lindley, *Introd. to Botany*, abstracted from a paper by Macaire, in *Bibliothèque Universelle*, XXXI., p. 244.

An additional circumstance of much interest as connected with this subject, has already been adverted to, (25) viz.: that plants may be poisoned by their own secretions. Thus the Poppy and the Lettuce may be poisoned with opium, and the Peach and Cherry with prussic acid; just as wasps are killed by their own stings, or serpents by their own bites.

Like animals also, plants may be destroyed by the inhalation of the poisonous gases. The sulphurous and muriatic acids, chlorine, and other acrid gases, produce death by corrosion; first attacking the tips of the leaves, and gradually extending their operation to the leaf-stalks. Sulphuretted hydrogen and ammonia act as narcotic poisons, causing the plant to languish and its leaves to droop, the exhaustion extending from leaf to leaf, and then down the stem, in a very striking manner. Carbonic acid gas is in like manner injurious to vegetation in the absence of solar light. Indeed, all the deleterious gases act upon vegetable life much more injuriously and promptly in darkness than in light. On the contrary, poisons introduced by the roots are much more active in the day, for at that time absorption is most prompt.

Plants have the power of resisting in a considerable degree the action of the deleterious substances they are made to absorb; getting rid of them by excretion from the roots (25). M. Macaire* proved this by a simple experiment with a plant of Mercurialis annua. He separated its roots into two parcels, one of which was introduced into a solution of acetate of lead, and the other into pure water. In a few days the originally pure water was found to be impregnated with acetate of lead, which must have been absorbed by the roots on one side of the plant, carried into the stem with the ascending sap, and excreted by the roots of the opposite side. The experiment was repeated upon several other plants, with the same result.

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* An abstract of M. Macaire's Memoir (referred to in p. 32) is contained in the 14th volume of the *Edinb. new Philosophical Journal.*

CHAPTER IV.

OF THE ORGANS OF REPRODUCTION IN FLOWERING PLANTS.

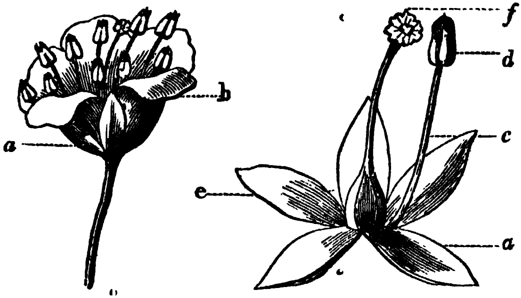
91. THE two preceding chapters have been devoted to the consideration of the organs of nutrition or vegetation; which are termed by De Candolle the fundamental organs of plants, not only because they comprise all that is essential to the life and growth of a vegetable, but for the reason that the organs to be described in the present chapter are mere modifications of them. The organs of vegetation not unfrequently serve for the propagation of plants: many species are perpetuated by bulbs, tubers, or offsets more readily than by seeds, and in this view buds might be classed with the reproductive organs (47). With these exceptions, which are rather apparent than real, all Flowering plants are propagated by seeds, the production and protection of which is the sole office of the flower and fruit.

The organs of reproduction in Flowering plants are essentially three, viz.: the Flower, the Fruit, and the Seed.

SECT. I. *Of the Flower in general; and of Bracts or Floral leaves.*

92. We pass in review the various parts of which a complete flower, like that of the Rhododendron, is composed. A complete flower consists of a number of distinct organs, arranged in several rows or whorls,

Fig. 59.

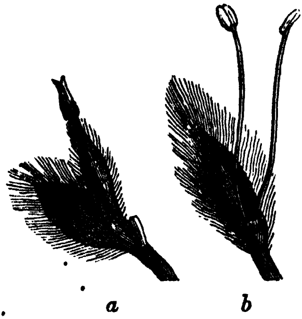


one within and above the other. The lower or outermost row is formed, in the example before us (*fig.* 59), of five bodies having the color and texture of leaves (*a*); these are called *sepals*, and the whole whorl taken collectively is named the *calyx* or flower-cup. Next within the calyx are five larger bodies, of a more lively hue and delicate texture (*b*); these receive the name of *petals*, and taken together they form the *corolla*. The calyx is the outer, and the corolla the inner series of the floral envelopes. Next within the corolla are placed several (in this case 10) slender club-shaped organs, called *stamens*; each of which consists of two portions, viz. a thread-like body termed the *filament* (*c*), and a thickened body surmounting the filament, which is named the *anther* (*d*). Soon after the flower expands, the anther opens at some part of its surface, and discharges a yellow powder-like substance, called *pollen*. Within the stamens and occupying the very centre of the flower, we observe an organ much resembling a stamen, except that it is thickened at each extremity, but more so at the base than the summit. This is the *pistil*. Its thickened base, called the *ovary* (*e*), is internally divided into several cavities or cells, containing rudimentary seeds; the slender portion is termed the *style*, and the little knob or disk (*f*) borne on the summit of the latter, receives the name of the *stigma*.

The pistil, accordingly, is composed of three parts, viz. the ovary, the style, and the stigma. Of these, the stigma and the ovary or seed-case are always present; but the style, which is merely a support for the former organ, is not uncommonly wanting. So likewise of the stamens, the anthers or pollen-cases are the only essential organs, the filaments being occasionally altogether wanting. Of the floral envelopes also, the inner series or corolla, whose office it is to protect the stamens and pistils and elaborate honey for their nourishment, sometimes disappears; and in such cases the calyx, which serves for the protection of the corolla, is occasionally wanting also.

A flower, then, reduced to the state of greatest simplicity may consist of an ovary, surmounted by a stigma, and one or more anthers with or without filaments; the other organs not being absolutely essential to a flower, though present in by far the greatest number of cases. The two essential organs, moreover, are not of necessity placed side by side in the same flower. Among the most simple of all flowers are those of the Willow (*fig.* 60.), which consist either of a pistil destitute of style, or of a couple of stamens, arising from the axil of a scale or rudimentary leaf. The one (*a*) is called the *pistillate* flower, and the other (*b*), containing stamens only, is termed the *staminate* flower. In this instance the stamens and pistils are not only separated, but are borne on different individuals.

Fig. 60.



A flower when furnished with both stamens and pistils is said to be a *perfect* flower, whether it has floral envelopes or not; but when these organs are placed in different flowers, the latter are termed *separated* or *diclinous*.

When both staminate and pistillate flowers are borne on the same plant, as in Indian-corn, they are said to be *monœcious* or in a single household; when, as in the Willow above-mentioned, they are situated in different individuals, they are called *diœcious*, or in two households.

When a perfect flower has both a calyx and a corolla, it is said to be *complete* (as in *fig.* 59); when it has neither, it is said to be *naked* or *achlamydeous*. (*Ex.* The Willow, *fig.* 60.)

93. The stalk, or transformed branch bearing flowers only, is named the *peduncle*, or flower-stalk; when the peduncle divides and bears several flowers, its ramifications are termed *partial peduncles* or *pedicels*.

94. All the organs just described clearly belong to the flowering apparatus, and not to the organs of vegetation; the peduncle being to the flower what the petiole is to the leaf; the calyx being destined for the protection of the corolla, and the corolla serving to nourish and protect the stamens and pistils; which latter organs are essential to the production of seeds, the end and aim of the whole flowering apparatus. But below the calyx, and yet above the true leaves, there often exist several bodies, seemingly intermediate between the two, and of which it is difficult to say whether they should be ranked with the foliage, or with the parts of the flower. These bodies, whatever may be their appearance, receive the name of *bracts*.

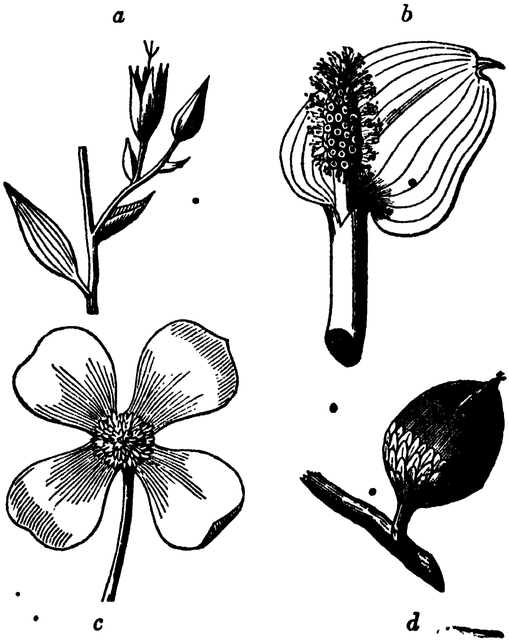
95. BRACTS are rudimentary or dwarfed leaves, often differing from the ordinary leaves of the plant only in their smaller size. Sometimes they lose their leaf-like texture and are reduced to little scales; in other instances they are as richly colored and conspicuous as the petals themselves.

Bracts may be situated either along the peduncle or its branches, or at its base. Strictly speaking, the latter only are called true bracts or floral leaves, and the former are termed *bracteoles* or bracts of the second order (*fig.* 61, *a.*). The two are often confounded, but it is sometimes necessary to distinguish them. Colored bracts are sometimes seen in several species of

Salvia or Sage, and also in Castilleja coccinea,* which owes all its beauty to its conspicuous and deep scarlet bracts.

A colored bract, somewhat rolled together, enclosing a bunch of flowers as in a sheath, is called a *spathe*. The curious envelope of Arum triphyllum and the petaloid bract of Calla palustris (*fig*. 61, *b*.) are examples of this. Spathes are only met with in Endogenous plants, being particularly large in Palms, in which they are not unfrequently as much as ten or twenty feet in length.

Fig. 61.



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* *Euchroma* of Nuttall.

When several bracts are collected into a whorl or, closely crowded together, they form an *involucre*. Umbels are usually furnished with an involucre at their base (*fig.* 68, *b.*). The whorl of smaller bracts which subtends the base of each little umbel is called an *involucel* or *partial* involucre. The involucre of those heads or dense assemblages of flowers which have been improperly named compound flowers (such as the Sun-flower and Marigold), resembles a calyx except that it encloses a great number of flowers (*fig.* 68, *d.*). Linnæan botanists term such an involucre a common calyx, and some authors call it a *periclinium*. but it scarcely requires a distinct name.

Involucres are sometimes colored and petal-like, as in the Flowering Dogwood (*Cornus florida*) (*fig.* 61, *c.*), whose showy involucres, often mistaken for petals, give the name to the plant. The leaves of an involucre sometimes grow together by their margins more or less completely, as in a few Umbelliferous plants, forming what is improperly called a one-leaved involucre.

Occasionally it happens that several whorls of scale-like bracts being crowded together grow into a cup-shaped body surrounding the fruit, called a *cupule*, as in the acorn (*fig.* 61, *d.*). The fruit of the Chestnut, Beech, and nearly all Amentaceous trees, is furnished with a cupule.

96. Bracts form the only covering to the flowers in the Cyperaceæ or Sedge-grass tribe, which have either no calyx or corolla, or only the rudiments of these organs in the form of little scales, or more commonly, bristles, as in the Club-rushes (*Ex.* Eleocharis obtusa, *fig.* 62, *a.*). A few Cyperaceous plants, however, exhibit these rudiments of floral envelopes, in a somewhat petal-like form (*Ex.* Fuirena, *fig.* 62, *b*). These grow together by their edges in the Carices or true Sedges, forming a bottle or urn-shaped body* which encloses the ovary, &c.

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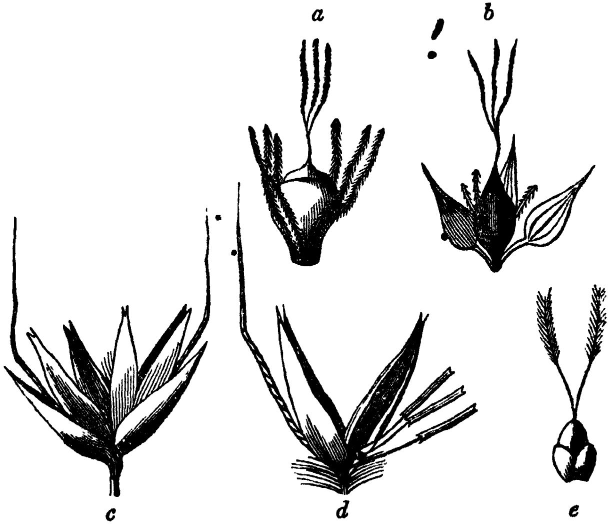
* Nees von Esenbeck applies to these bodies the name of *perigynium*, under whatever form they may appear. The name has the advantage of being unexpressive of their nature, and if they are some-

The flowers of Grasses are wholly destitute of calyx and corolla, their envelopes consisting of bracts only. Each little head of flowers in this tribe is called a *spikelet* (*Ex. fig.* 62, *c*, which represents a two-flowered spikelet of a species of Aira). There are two empty bracts at the base of the spikelet, not exactly opposite, one being placed a little higher than its fellow; these are called *glumes;* the lower one is termed the *inferior* or *outer*, and the opposite one the *superior* or *inner* glume. The glumes include two flowers in this instance, but in other Grasses (Poa, Bromus, &c.) a much greater number, and in several (Agrostis, Stipa, &c.) only a single flower. Each flower is provided with a

Fig. 62.



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times transformed stamens (as Nees supposes), the term should retained. On the other hand, if they are, as we think, the rudiments of a perianth or an inner series of bracts (as they probably are in some cases), no special name is required for them.

pair of bracts of a second order, or bracteoles, much resembling the glumes (*fig.* 62, *d.*), which may be termed *glumelles* or *paleæ.*[*] Each palea is termed a valve: the one the *lower* or *outer*, and the other the *upper* or *inner* valve. The lower palea is often provided with a beard, which when it proceeds from the apex of the valve is called a *seta* or *bristle*, but when it protrudes from the back of the palea, as in our figure, and also in the Oat, it is called an *awn.*[†] The glumes sometimes bear bristles but are never *awned.*

Within the paleæ at the base of the ovary one or two minute scales may often be perceived. (See *fig.* 62, *e*, which represents the pistil of *d* with these little scales attached.) We may consider these either as the rudiments of a calyx, or of a third order of bracts: they have received various names;[‡] that of *squamulæ*, or little scales, should for the present be retained.

SECT. II. *Of the Nature or theoretical Structure of the Flower.*

97. *A flower is a transformed branch; all its organs being leaves which have undergone a peculiar metamorphosis.* This proposition, upon which the modern views of the structure of the flower and fruit are based, originated with Linnæus. That great reformer of systematic botany, however, was not aware of the important applications of this theory, which was entirely neglected until the year 1790, when it was revived and presented in a novel manner by the illustrious Goethe. His little treatise entitled "An attempt

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[*] The *corolla* of Linnæus, the *calyx* of Jussieu, the *perianth* of Brown, the *glumelles* of De Candolle, the *paleæ* of Kunth and others. Either of the latter names may be adopted.

[†] The bracts of Grasses are modified sheaths of leaves, or in other words petioles destitute of lamina; the awn is the midrib of the lamina projecting from below the apex of the valve; and bristles are extensions of the midrib or principal veins.

[‡] The *nectary* of Linnæus, *lodicula* of Beauvois, *squamulæ* of Jussieu, Brown, &c., *glumellula* of Desvaux.

to explain the metamorphosis of plants,"* at first excited little attention; but after the lapse of several years, having been adopted and illustrated by Du Petit-Thouars, Roeper, De Candolle, and others, it became, and still continues to be, the commonly received view of botanists on this subject.

We shall here advert to a few of the reasons which may be adduced in favor of this proposition, and others will be incidentally noticed as we proceed.

In the first place, it may be remarked that the situation of flowers on the stem and branches is the same as that of leaf-buds, both proceeding from the axils of ordinary or imperfectly-formed leaves, as we shall have occasion more especially to notice in the section on Inflorescence.

Another series of arguments may be adduced from the facility with which the several parts of the flower change into each other and, either directly or indirectly, into true leaves.

That bracts are leaves deprived of a portion of their nourishment by the development of flowers in their vicinity, and consequently more or less checked in their growth, will scarcely be doubted; the transition being often so gradual that it is impossible to say where the one set of organs ends and the other begins. If this be the nature of bracts, it follows that all their modifications, such as the spathe, the involucre, and the scales of the cup of an acorn, are also imperfect leaves.

That the calyx is a whorl of transformed leaves, is capable of complete demonstration. In the first place, there is often such a plain transition from bracts to sepals, that no positive line of demarcation can be observed. In the Mallow, the Hollyhock, and many other plants of the Mallow tribe, a whorl of bracts exists at the base of the calyx, so closely resembling sepals, that these plants are usually said to have a double calyx. The Strawberry has five little bracts alternating with the five sepals, and only distinguishable from them by their smaller size. In the Camellia Japonica, now so common in gardens, and in the Gordonia of the Southern states, a plant of the same family, the bracts and sepals are so entirely similar that no one can say in what the distinction lies. Moreover, sepals sometimes change into true leaves; those of the Rose are commonly dilated petioles only, but in many species they bear a lamina upon their summits, and it occasionally happens that this lamina is pinnated and undistinguishable from the ordinary leaves of the plant.

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* *Versuch die Metamorphose der Pflanzen zu erklären.* 1790, ed. 2d, 1817.

The transition of sepals into petals is so easy, and the limits of the two often so absolutely indefinable, that the difference between the calyx and corolla has always been a debatable ground in botany. Although in a majority of cases they present a marked difference in their appearance, yet very frequently there are no distinguishable limits between the two. The calyx indeed is usually green and leaf-like, but in very many cases it is delicate in texture and richly colored, when it is said to be petaloid. In Illicium (the Anise-seed tree of the Southern states) and Calycanthus (Carolina Allspice) the coverings of the flower consist of several whorls of transformed leaves, all nearly alike in color, texture, and shape; but how many of the innermost are to be called petals, and in what manner the remainder are to be divided between sepals and bracts, wholly depends upon the fancy of the person who counts them.

The calyx and corolla are confounded in the Orchis and Lily tribes, and in a great part of Endogens. In the Lily and Tulip the floral envelopes are often green on the outside and richly colored within. In fact, the only absolute way of distinguishing them, is to call the outer whorl calyx and the inner one corolla; but in those cases where only one whorl exists, it is impossible to say which is absent, or whether, as is most probable in many instances, the two are not confounded together in a single row. In this case it is agreed to term the floral envelopes the *perianth*, which simply means the covering of the flower, expressing no opinion concerning its nature. Such being the relation between the calyx and corolla, whatever is true of the one must be true of the other; and if sepals are modified leaves, as has been already proved, so also are petals. If the parts of the flower are really modified leaves, we might expect them sometimes to revert to their primitive state. Now this occasionally happens, not only with sepals, whose leaf-like texture renders it less remarkable, but also with petals; examples of petals changed into true leaves having been observed in several species by nearly all botanists from the time of Linnæus to the present day. A great variety of instances might be adduced in support of this part of our proposition, but the few which have been noticed, seem to be perfectly conclusive upon this point, and to place the nature of the floral envelopes beyond the possibility of a doubt.

The stamens occupy one or more whorls next within the corolla, usually exhibiting not the remotest resemblance to leaves; yet that they do not differ from them in nature, may be as conclusively proved as in the case of the floral envelopes. The transition of petals into stamens may be observed in double roses, pæonies, tulips, and pinks; and in all these examples, especially in the last, the manner in which this transformation takes place may be distinctly traced. The lamina of the inner row of petals folds up, forming an anther, the two lobes of which correspond to the sides, and the connecting portion to the midrib of a leaf, while the claw answers to the filament. Between the perfect stamens and the outer row of petals all sorts of intermediate bodies may be observed,—filaments bearing at their summits an anther on one side and the distorted limb of a petal on the other, next imperfectly-formed petals with very small limbs, and finally larger petals with more perfect limbs. The same curious transformation may be traced in all the double flowers so common in every garden.

It is interesting to observe this change in the cultivated Larkspurs and the Columbine (*Aquilegia vulgaris*). The petals of the Columbine "consist of a long sessile purple horn or bag, with a spreading margin; while the stamens consist of a slender filament, bearing a small oblong two-celled yellow anther. In single and regularly-formed flowers, nothing can be more unlike than the petals and stamens; but in double flowers the transition is complete. The petals which first begin to change provide themselves with slender claws; the next contract their margins and acquire a still longer claw. In the next change, the purple' margin disappears entirely, and two yellow lobes like the cells of the anther take its place, and the horn, diminished in size, no longer proceeds from the base as in the genuine petal, but from the apex of the now thread-like claw. In the last transition the lobes of the anther are more fully formed, and the horn is scarcely longer than the anther, retaining however its purple color. The next stage is the perfect stamen." *

It may be objected (although the objection has not the least value) that these illustrations are drawn from plants which have been cultivated for a long time, and are accordingly in an unnatural state. We turn, therefore, to one example out of many among our native plants, viz. the White Water-lily (*Nymphæa odorata*), which, growing in almost every pond throughout the United States, is familiar to most persons.

In this plant, the transition of sepals into petals, as well as of petals into stamens, may be distinctly traced The calyx, or exterior series of the floral coverings, consists of four or five sepals which are green on the outside but whitish and somewhat petal-like within The corolla is made up of several whorls of petals, the outermost of which are sometimes slightly tinged with green. Between the well-formed petals and the stamens, there is a row of organs which are neither the one nor the other, but both in part; they are reduced petals, the margins of which are turned inwards at the summit, and enclose a little pollen. The more perfect development of the pollen-cells, and the greater attenuation of the lower part of the petals, completes the transition into genuine stamens.

The conversion of stamens into green leaves is very uncommon, yet it has been seen in a few instances, completing the chain of proof, that the stamens, as well as the floral envelopes, are modified leaves.

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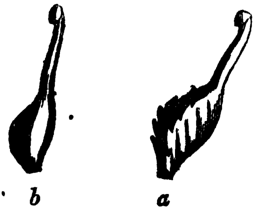
* Lindley, *Introd. to Botany*, p. 515.

The pistils, the innermost of the floral organs, occupy the very centre of the flower. They vary considerably in number, the Pea and the Cherry having a single pistil, the Columbine and the American Cowslip (*Caltha palustris*) having several placed in a single row like a whorl of leaves.

In the Nigella damascena, or Fennel-flower of gardens, the pistils grow together by their ovaries, their styles remaining separate. In the Poppy they grow together to their very tips, forming a single compound pistil. Nothing is easier than to establish the fact, that pistils are constructed in the same manner as the other parts of the flowering apparatus,—that a simple pistil is a folded leaf, and a compound pistil a whorl of similar leaves grown together. As this subject must necessarily be treated of at considerable length in another place (Sect. VI. of the present chapter), only a few of the leading proofs will here be noticed.

In double Roses, pistils are often transformed into petals, and not unfrequently into genuine leaves. Although they scarcely ever change into stamens, yet a few instances of this transformation are on record. There is a well known monstrous variety of the cultivated Cherry which furnishes the most conclusive proof of the nature of this organ. The place of the pistil is occupied by a green leaf somewhat folded together, and similar to the leaves of the branches except in its lesser size (*fig.* 63, *a.*). If we compare this leaf with the perfect pistil of the Cherry (*fig.* 63, *b.*), we observe that the folded lamina answers to the ovary, the midrib projecting beyond the lamina to the style, and its slightly dilated apex to the stigma. The leaf is sessile in this instance, but the petiole makes its appearance in several plants of the Pea tribe, in nearly all Capparideous plants, and

Fig. 63.



in the Coptis trifolia or Gold-thread (*fig.* 79, *d.*). The fruit is the ripened pistil; hence, if the pistil be a modified leaf so also is the fruit, for no new part is added to the fruit during its growth. It accordingly follows, strange as it at first sight appears, that a cherry or a peach is essentially nothing more than a transformed leaf. The leaf is always folded upwardly as is seen in the monstrous cherry (*fig.* 63.); the stone or hardened inner portion is therefore the upper stratum of the leaf, and the veins may be readily traced in its sculpturing. The lower stratum of parenchyma (which has been seen (*fig.* 37.) to have a different and much more loose structure than that of the upper stratum), being filled with fluid, gradually changes its color, and becomes the pulpy portion of the fruit. The skin is accordingly the cuticle of the lower surface. The change in texture is similar to that which habitually occurs in the thickened leaves of succulent plants, and the same alteration in color happens to all leaves in autumn. Thus far of simple fruits; and as compound fruits are collections of pistils, it follows that all fruits are modified leaves.

When, however, botanists affirm that all the organs of the flower are transformed leaves, they should not be understood to say that these parts ever existed as actual leaves, but that their nature and origin are the same;—that the little scales which surround a growing point or bud, are all just alike during their early existence;—that they sometimes grow into leaves, and, under other circumstances, into the organs of flowers. There is a period, therefore, when the destination of a bud is not fixed; it may extend into a branch, produce genuine leaves with their corresponding leaf-buds, and thus serve for the increase of the individual: on the other hand, it may at an early period cease to elongate, the rudiments of leaves growing into floral coverings and organs of fructification, and thus, changing its destination, serve for the perpetuation of the species. An abundance of nourishment, or whatever else tends to increase the vigor of vegetation, promotes the formation of leaf-buds: on the contrary, whatever causes give a temporary check to vegetation, facilitate the production of flower-buds. Hence, flower-buds are formed during the winter, and plants in rapid vegetation may often be made to flower by arresting their growth. Hence, also, the tendency of the organs of the flower to revert to leaves, especially in cultivated plants, whenever they are in a state of rapid and luxuriant growth. Thus, "in unusually warm and early springs, a great number of the flower-buds of Apples and Pears are changed into leaf-buds by the rapid development which they undergo, breaking up the whorls of their flowers, and throwing an excessive quantity of sap into the organs which had been destined for flowering purposes, and thus converting them into leaves."

98. A flower, accordingly, is a very short branch, provided with several whorls of peculiarly modified leaves. It consists of at least four whorls when all its organs are present, of which the two outer (calyx and corolla) serve as organs of protection for the two inner ones; but as each organ may be composed of two or more whorls, this number is often considerably increased. Like ordinary leaves, the parts of the flower are capable of producing buds in their axils, explaining those rare anomalies in which a flower has a branch or another flower growing out of itself.

It also follows, such being the structure of a flower, that its parts will be subject to the same laws of arrangement as ordinary leaves. Each whorl of floral organs accordingly, as in genuine leaves, alternates with the one which precedes it: thus, the petals normally alternate with the sepals, and the stamens with the petals &c.; and if there be two rows of sepals or petals, they alternate with each other.

A whorl of leaves consists of the leaves of a single spire (60), the internodes being suppressed, and each spire has the same number of parts. The whorls of the floral organs are of the same nature; consequently, the number of parts in each row should be the same. If the calyx consists of five sepals, the corolla should also consist of five petals, and there should be five stamens and five pistils, all these parts being respectively alternate with one another. Such a flower would be perfectly symmetrical, and numerous examples of this kind exist; but not uncommonly, some part of this symmetrical arrangement is obscured or destroyed by various counteracting circumstances, which are now, however, so well understood, that a skilful botanist finds little difficulty in detecting the true symmetry of a plant through all its disguises. All exceptions to this regular correspondence in the number and relative position of the organs of a flower, are owing to the multiplication or abortion of parts, or their adhesion to each other.

Thus, as to multiplication of parts, Trillium has a calyx of three sepals, three petals which alternate with these, six stamens of which three are alternate with the petals and three opposite them, and three combined pistils. Here the perfect symmetry of the flower is interrupted by the development of an additional whorl of stamens, which, on account of the closeness o their origin, seem to form but a single row. A Cherry has a calyx of five sepals, a corolla of five petals alternate with the calyx, and twenty stamens: here four rows of stamens are developed, the flower being otherwise symmetrical. The Poppy has a calyx of two sepals, a corolla of four petals, and a great number of stamens, which are however some multiple of two or four. The Blood-root (*Sanguinaria Canadensis*) has two sepals, either four or six times as many petals, six times as many stamens, and two pistils grown into one. Hundreds of analogous examples might be mentioned; all serving to prove, that when the number of parts is not the same in each whorl, it is usually some multiple of the number in the first or outermost series.

The symmetry of flowers is frequently masked by the abortion of some of their parts. Thus Gratíola or Hedge-hyssop has a calyx of five sepals, five petals united almost to their tips, and only two perfect stamens. Here the three stamens which are needed to complete the series, have disappeared entirely in G. Virginica; while in another species (*G. aurea*) two minute filaments stand in the place of two of the stamens, no trace of the fifth being observable. That the two little filaments of Gratiola aurea are really the rudiments of stamens, is evident, first from their situation being alternate with two of the lobes of the corolla, and secondly, from the fact that most other plants of the same family (the Digitalis or Foxglove for example) have a pair of perfect stamens, a little shorter than the other two, occupying the same place. All these plants however require another stamen to render them symmetrical. The rudiment of this stamen is seen in the Snap-dragon; in Pentstemon it appears in the form of a bearded filament, longer than the perfect stamens; and the symmetry is perfect in the Mullein, which has five perfect and nearly equal stamens.

The flowers of the Pea tribe have a calyx of five sepals and a corolla of five petals, but in one genus (Amorpha) all the petals except the upper one have disappeared entirely, and in another (Erythrina) the four lower petals, although they have not wholly disappeared, are very inconspicuous.

Sometimes a complete whorl of organs is abortive. The calyx of the Dogwood and Holly is reduced to a minute four or five-toothed rim, and in compound flowers it consists of little scales or bristles only. The petals commonly disappear in Isnardia palustris, and always in Anemone and Thalictrum. The flowers of Moonseed (*Menispermum Canadense*) regularly lose by abortion either their stamens or pistils, and the existence of separated or diœcious flowers is probably due to this same cause in all instances. The pistillate flowers of the Willow lose by abortion both the calyx, corolla, and stamens, and the staminate flowers are deprived in the same manner of every thing except their stamens.

Deviations from the normal structure caused by the adhesion of neighboring parts, are exceedingly numerous: the sepals often unite into a cup-shaped calyx; or the petals, growing together by their edges, form a corolla of a single piece, as in Convolvulus; or the stamens unite by their filaments into a tube, as in the whole Mallow tribe; or by their anthers into a ring, as in all Compositæ. This kind of union.

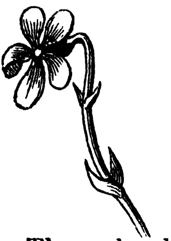
however, obscures the symmetry of the flower very little, since the parts of the whorl seldom cohere quite to their tips; the number of lobes or sinuses in the border of such a calyx or corolla being an accurate index of the number of sepals or petals of which the organ is composed. It frequently happens that these organs unite unequally, and then some little difficulty is experienced in ascertaining the real number of parts. Thus most plants of the Mint tribe have a two-lipped corolla, the upper lip being made of two petals, as the little notch at its summit proves, and the lower one consisting of three similar petals united almost to their summits: the sepals are frequently combined in the same manner. It is in allusion to this circumstance that the plants of the Mint tribe are called *Labiatæ*, or Labiate plants. Not only do similar parts cohere, but different organs have the same tendency to unite with each other. The calyx often adheres to the ovary more or less completely; the petals and stamens adhere to each other, and both to the calyx; and in one curious family (the Orchideæ) the stamens adhere to the pistil. It may be laid down as a general rule, that all organs situated very close to each other may be expected occasionally to grow together. As numerous examples of this kind will be hereafter mentioned, they only require a casual notice in this place.

A careful attention to the simple principles of floral structure, which have been thus cursorily indicated in the present section, will enable the student to understand the true structure of all the flowers he meets with, and to explain with the greatest ease hundreds of deviations from ordinary forms, which are otherwise perfectly inexplicable. It is to the establishment of these principles, more than any thing else, that Botany owes the place which it now so deservedly holds among the exact sciences.

SECT. III. *Of the Inflorescence.*

99. The term *inflorescence* is used to denote the manner in which flowers are arranged upon the stem or branches. Flower-buds being, like leaf-buds, placed at the extremity of a branch or in the axils of leaves, the most simple of all modes of inflorescence is when a single flower is borne on the summit of a branch or in the axil of a leaf, as in the Violet (*fig.* 64.).

Fig. 64.

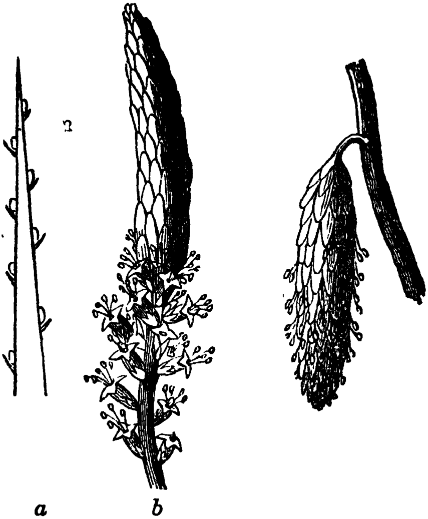


This is precisely the condition of a leaf-branch which produces only a terminal bud. But as a leaf-branch usually produces axillary buds also, so likewise a flower-branch may bear flowers in the axils of bracts throughout its whole length, as in a bunch of currants. The main stalk of such a modified branch is called the *peduncle*, and the little stalks which support each flower receive the name of *pedicels*. The peduncle is also termed the *rachis*, or axis of the inflorescence, when it passes from one end of a bunch of flowers to the other without dividing, as in a bunch of currants, &c.

100. When the lateral buds of a flower-branch grow into flowers without forming pedicels, a *spike* is the result, as in the common Plantain (*fig.* 65, *b.*) and the annexed diagram (*fig.* 65, *a.*). The axis of a spike continues to lengthen producing new flowers at its apex for some time, which all arise from lateral buds; on this account such an inflorescence is said to be *indeterminate*.

Several modifications of the spike have received distinct names. An *ament* or *catkin* (*fig.* 65, *c.*) is a spike of naked flowers surrounded by scale-like bracts; as in the Willow and Poplar. The flowers of an ament are usually staminate or pistillate only, and the whole falls off in one piece after flowering. A *spadix* is a crowded spike with a fleshly axis, surrounded by a spathe (*fig*. 61, *b*.). This is only found in the Arums and the Palms.

Fig. 65.



101. When all the flowers of such a flower-branch stand on pedicels of equal length, a *raceme* is formed, as in the Currant and Wild Cherry, (*fig*. 66, *a*.). The only difference between a raceme and a spike is, that the former has conspicuous pedicels, and the latter scarcely any.

102. A *panicle* (*fig*. 66, *b*.) is a raceme which bears flower-branches in the place of single flowers. This kind of inflorescence is very common in the Grasses. A panicle is called simple, compound, or decompound, according to the degree of its ramifications. When the upper and lower branches of a panicle are shorter than the middle ones, as in the Lilac, we have a *thyrse*.

All these forms of inflorescence are strictly indefinite, there being no terminal flower, and their length depends principally upon the nourishment the branch

103. But when the bud terminating the branch becomes a flower, the inflorescence being incapable of further elongation is generally broader than long whenever it consists of many flowers. This kind of inflorescence is said to be *determinate*. A solitary terminal flower exhibits it in its simplest state (see diagram, *fig*. 67, *a*.), the bracts indicating the situation of several undeveloped buds. When flowers appear in the axils of these bracts, and are elevated on pedicels nearly as high as the central flower, a *corymb* (*fig*. 67, *b*.) is formed. This term, however, is often employed in an adjective sense; thus we speak of a corymbose panicle or raceme, or even of corymbose branches.

Fig. 66.

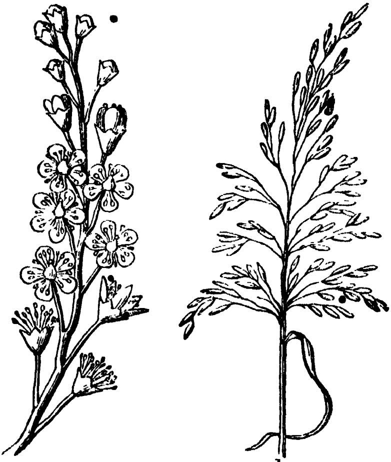
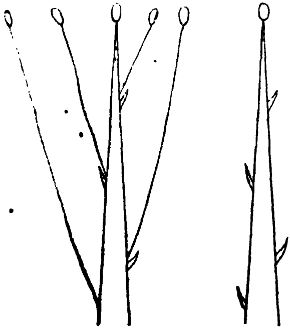
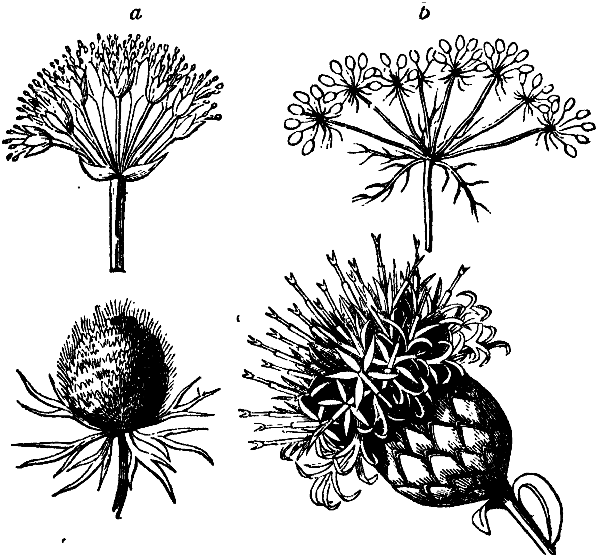


Fig. 67.



104. When the primary axis is very short, the flowers having distinct pedicels which all seem to start from the same point, we have a simple *umbel* (*fig*. 68, *a*.), as in the Milk-weed (*Asclepias*) and the Onion. A simple umbel is, accordingly, a raceme with a very short axis. If the secondary axes (or, as they are called, *rays*) of the umbel arise from the primary ones in a similar manner, a *compound umbel* is the result (*fig*. 68, *b*.), as in the Parsnip and all similar plants. A compound umbel has the same relation to a panicle that a simple umbel has to a raceme.

Fig. 68.



105. A *Capitulum* or *head* may be considered either as a simple umbel with sessile flowers, or as a spike with a very short axis. *Ex*. Eryngium aquaticum (*fig*. 68, *c*.), Cephalanthus occidentalis or Button-bush,

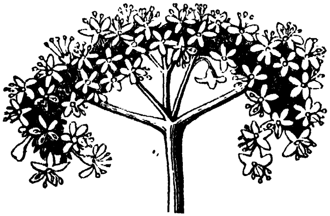
The axis or rachis of a capitulum is called a *receptacle*, and the involucre which often surrounds its base is, as has been already mentioned, a series of crowded bracts.

What are called compound flowers, as the Sun-flower, Aster, and Centaurea (*fig.* 68, *d.*), are truly heads or compact bunches of flowers. We may obtain a correct idea of their nature, by considering such an inflorescence to be a very dense corymb, the branches of which have grown together, so as to form a flattened or conical receptacle. The flower-bunch taken together has been called by different authors an *anthodium*, a *cephalanthium*, and a *calathium* or *calathidium*. To the receptacle the terms *clinanthium* or *phoranthium* have been applied; and the involucre is sometimes termed a *periclinium*, but these special names are scarcely required.

106. All the foregoing forms of inflorescence have what is termed the *centripetal* mode of flowering, that is, the lower or outermost flowers of the bunch expand first, these being really the oldest, and the others follow in regular succession to the summit or centre of the bunch. There are, however, many cases in which the central flowers open first and the lowermost or external ones last; forming what is termed the *centrifugal* order of flowering. In these cases, the bud which terminates the stem is transformed into a flower, and being the earliest formed is the first to expand. The stem itself cannot elongate further, but the accumulation of nourishment causes the development of new branches in the axils of the bracts or uppermost leaves. These are terminated by a solitary flower, which again produces branches from the axils of its bracts in the same manner; the flowers developing in the order of their age, beginning at the centre. This mode of flowering may be studied to advantage in the Chickweeds (*Cerastium* and *Stellaria*), in which it is recognisable at once by the solitary flower (destitute of bracteoles) in each fork of the branches. Although called a determinate inflorescence, it is really as indefinite in duration as any of the preceding forms; for although the main stem cannot

extend beyond the central flower, the number of lateral branches is limited only by the quantity of nourishment and the energy of the plant. Thus many Chickweeds produce flowers during the whole summer. Their inflorescence is usually called a dichotomous panicle: it should rather be termed a *paniculate cyme*. In other cases of centrifugal expansion, the primary branches start from the same point, being all formed at the same time, and the secondary branches are short and corymbose, so that the bunch of flowers is nearly level-topped. This arrangement, of which the Elder and Dogwood are examples, is called a *cyme* (*fig.* 69.). It resembles an umbel in its primary branches, and a corymb in their ramifications; but is distinguished from either by the solitary flower in the forks of the branches, and the centrifugal order of development. The central flower is sometimes abortive at an early period, when the resemblance to a corymb is still more close.

Fig. 69.



A cyme reduced to a few flowers is called a *verticillaster*. Two reduced cymes of this kind situated in the axil of a pair of opposite leaves, form the inflorescence of Labiate plants, which has been termed a *verticel* or *whorl*. True whorled flowers are uncommon, existing only in Myriophyllum or Water Milfoil, and some other plants with whorled leaves.

A compact cyme with few and short branches is called a *fascicle;* examples of which are seen in the Sweet-William, and several other plants of the Pink tribe. The centrifugal mode of flowering distinguishes it from a contracted corymb.

A cyme with its flowers so nearly sessile that it seems to be a capitulum, is called a *glomerule:* this is of rare occurrence, but is observed in a few plants of the order Compositæ.

107. The two systems of inflorescence are sometimes combined, producing, at first sight, no little difficulty in the application of these principles. In some cases the stem or axis is prolonged after the manner of an indeterminate inflorescence, while the lateral branches follow the centrifugal mode. This happens in Labiate plants, in which the main stem grows indefinitely by its extremity; but the bunches of flowers in the axils of the leaves are true cymes, as is denoted by the order in which the flowers expand. Again, in most Compositæ the stem branches in a centrifugal manner, although the flower-heads expand in the centripetal mode.

108. There are a few cases of anomalous inflorescence, which seem to require a passing notice. An apparent deviation from the ordinary arrangement of flowers is observable in the Vine, as well as in some other plants of different families. The Vine bears its clusters of flowers exactly opposite the leaves, just as if one of the leaves had changed into a raceme. Here the raceme really occupies the summit of the stem; the continuation of the latter being a branch from the axil of the uppermost leaf, which grows so vigorously that it is not turned to one side, but takes the same direction as the main stem. The zig-zag appearance presented by many stems with this inflorescence, renders the explanation easy to be comprehended.

A peduncle arising from or beneath the surface of the ground, is called a *scape*, and sometimes a radical peduncle. As the root, however, bears no leaf-buds, it cannot produce flowers; all scapes therefore proceed either from a subterranean stem, as in Sanguinaria and the subcaulescent Violets, or from the axils of a cluster of leaves arising from the neck, as in the Strawberry.

In several species of Solanum, the peduncles spring from the stem at some distance from the axils of the leaves. In Villarsia and Hibiscus Moscheutos, the petiole seems to bear the flowers. These apparent anomalies are probably owing (in the last-named instance unquestionably) to the partial cohesion of the peduncle with the stem or petiole. In Tilia, the peduncle is united with the midrib of the floral leaf.

Flowers are erroneously said to be borne upon the leaves in the Cactus or Prickly-Pear, the dilated and succulent stems of the plant being mistaken for leaves.

SECT. IV. *Of the Floral Envelopes.*

109. The coverings of a flower generally consist of two whorls; the outer of which is termed the *calyx* and the inner the *corolla.*

Linnæus called all the floral envelopes taken together the *perianth*, but this name, as well as the corresponding one of *perigonium*, is now chiefly employed for the floral envelopes in the cases where the calyx and corolla are confounded together, apparently forming a single covering, as in the Lily and Tulip; or where being composed of several whorls we are unable to ascertain the limits of each organ, as in the Calycanthus or Carolina Allspice (p. 160).

There being no means of distinguishing a calyx from a corolla excepting by their relative position (97), when a single whorl only exists it is called a calyx whatever may be its texture or color. A calyx, therefore, may exist without a corolla, but not a corolla without a calyx. Care must be taken, however, in the application of this rule, that the calyx does not escape our notice, as when it adheres to the ovary and its existence is indicated solely by the presence of a few scales or bristles which form its border; as in all Compositæ, the Valerian and Scabious tribes, &c.

It is worthy of remark, that the prevailing number of parts in each row of the floral coverings, is five in Exogenous plants, and three in Endogenous plants. Exceptions to this rule are of frequent occurrence, especially in the first-named division, although the numbers 5 and 10 are much the most common. By far the greater part of Endogens exhibit 3 sepals and 3 petals, or some multiple of this number.

110. The mode in which the sepals and petals are arranged in the flower-bud is termed their *æstivation* or *præfloration.* It is found to be of considerable consequence in practical botany, and its several kinds have

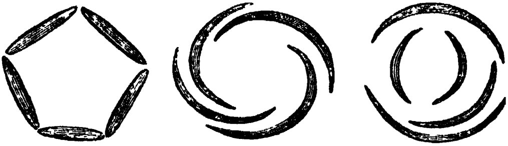
received distinctive names. There are three principal modes of æstivation, viz.:

1st. *Valvate* (*fig.* 70, *a.*); when the sepals or petals fit by their edges, not overlapping each other. *Ex.* the sepals of the Mallow tribe, and the petals of Umbelliferous plants.

2d. *Imbricated* (*fig.* 70, *b.*); when the outermost pieces cover the margins of the inner, as in the calyx of Hypericum. Of this there are many subordinate varieties.

3d. *Twisted* or *contorted* (*fig.* 70, *c.*); when each piece overlaps its neighbor by one margin, the other margin being covered in the same way by the adjacent piece, the whole appearing to be more or less spirally twisted. The petals of the Mallow and of Hypericum exhibit this kind of æstivation.

Fig. 70.



Most irregular flowers have some peculiarity in their æstivation, but these varieties are usually reducible to one of the three preceding forms.

It is worthy of notice, that the æstivation of the calyx and corolla is not always of the same kind. In the Spiderwort (*Tradescantia*), the calyx has a valvate, and the corolla an imbricated and crumpled æstivation The calyx in the Mallow tribe is valvate, and the corolla twisted. The Flax has the calyx twisted one way, and the corolla in the opposite direction.

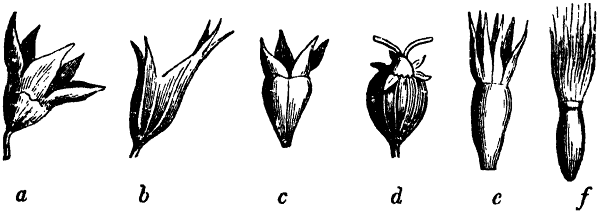
1. The Calyx.

111. The **calyx** is usually of a green color and leaf-like texture, and is more permanent than the corolla; but these characters are not universal, many plants

having a *colored* calyx, *i. e.* exhibiting some other color than green. In Fuschia it is larger and much more richly colored than the corolla. In all Cruciferous plants it drops off at the same time as the petals, and in plants of the Poppy tribe still earlier.

Each piece, or transformed leaf of which the calyx is made up, is called a *sepal.* Sepals are either distinct or united by their margins more or less extensively. When they are distinct, the calyx is said to be 2-, 3-, 5-, or poly-sepalous, according to the number of sepals. When they are united forming one body, the calyx is said to be *monosepalous* or one-sepaled, and to be parted, cleft, or toothed, according to the degree of cohesion, this language being understood to mean that the several sepals have partly or entirely grown together, and not that the calyx is a simple cup or tube, notched at its border or summit. To avoid this ambiguity, De Candolle proposes to call a calyx with united sepals a *gamosepalous* calyx, a term which correctly expresses the nature of the organ. The older botanists, not using the name *sepal,* called such a calyx *monophyllous,* or one-leaved.

Fig 71.



The coherent portion of a monosepalous calyx is termed the *tube,* and its spreading border the *limb* (*fig.* 71, *a.*). If the sepals are all united to their very tips, the calyx is said to be *entire;* the number of sepals entering into its composition being ascertainable only by analogy, or by observing the number and arrangement of the veins. Sometimes a part of the sepals cohere to a greater extent than the others, giving rise to a two-lipped or *bilabiate* calyx, as in most Labiatæ (*fig.* 71, *b.*). In a few instances the sepals cohere so as to form a closed cup, placed over the flower like an extinguisher upon a lamp; the growth of the corolla and stamens at length detaches the calyx by its base, and it falls off when the flower expands. This is seen in Eschscholtzia, a native of the western coast of America, now so generally introduced into our gardens.

The calyx usually falls soon after flowering, but occasionally it remains, becoming juicy or pulpy and acquiring a considerable size, as in the Strawberry-Blite and the common Wintergreen (*Gaultheria procumbens*); the fine red berries, as they appear to be, in these cases consisting of the thickened and pulpy sepals.

112. The calyx being the exterior, and the pistils the innermost or uppermost of the floral organs, the origin, or as botanists say the insertion, of the calyx is necessarily *inferior* or below the pistils. Sometimes, however, the tube of the calyx coheres with the surface of the ovaries, its border spreading from their summit on which it seems to grow; as in the apple. In this case the calyx is said to be *superior;* but it would be more accurate to say with the French botanists, that it is *adherent* to the ovary. We meet with all degrees of this adhesion. In some Saxifrages the calyx adheres to the ovaries about half their length; the urn-shaped calyx-tube of the Rose (*fig.* 81, *a.*) encloses, but does not adhere to the pistils; while the thickened and juicy calyx of the Apple is perfectly incorporated with the fruit.

113. Often, when the calyx is superior, or in other words adherent to the ovary with which its tube is intimately united, the limb is either altogether wanting or so changed from its ordinary aspect that the flowers are apparently destitute of calyx. Several examples drawn from plants of common occurrence will illustrate the great diversity in the appearance of a superior calyx. In Œnothera or Evening Primrose, the ovary occupies only the

lower part of the tube; in Ionardia, a genus of the same family, it occupies the whole tube (*fig.* 71, *c.*). In Umbelliferous plants, the limb of the calyx is reduced to five minute teeth (*fig.* 71, *d.*), and sometimes to a little rim or disk without teeth. In Compositæ the limb is called *pappus*, and consists either of several scales (*fig* 71, *e.*), or of a tuft of bristles or stiff hairs (*fig.* 71, *f.*), which we consider as the attenuated frame-work of the limb of the calyx.

2. The Corolla.

114. The corolla is generally the most conspicuous part of the flower, and is known by its delicate texture and lively color, which is scarcely ever green. These characters commonly appertain to the corolla; but it is more accurately defined as the series of floral envelopes intervening between the calyx and the stamens

The several portions of the corolla, or as they are termed *petals*, are alternate with the sepals, and either equal to them in number, or twice, three times, or some other multiple of their number. This is a necessary consequence of the laws which govern the arrangement of leaves (98).

In the young flower-bud the petals are much smaller than the calyx, but in the expanded flower they are usually considerably larger; sometimes, however, they remain in the form of little scales, and in many plants are altogether wanting. They are almost always articulated with the receptacle, and therefore fall off sooner than the calyx; sometimes they have no articulation, and are *persistent*, remaining a longer time than usual, or withering away without falling off, as in Campanula or Bell-flower.

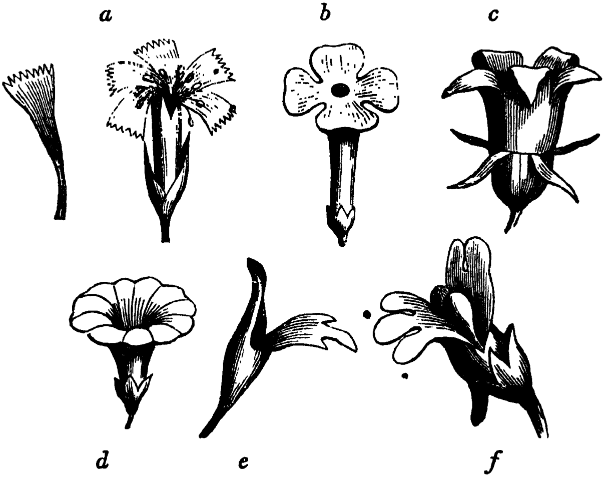
The structure of petals is like that of genuine leaves, except that the cellular tissue is more delicate, and the fibrous frame-work or veining consists of spiral-vessels without any woody fibre. They frequently exhibit stomata or breathing-pores.

115. When the petals are all distinct and separate, the corolla is said to be *polypetalous;* when their edges grow together so as to form a tube, the corolla is com-

monly called *monopetalous*, as in Campanula and Convolvulus. This term is open to the same objections as that of monophyllous or monosepalous as applied to the calyx. A truly monopetalous or one-petaled corolla exists in Amorpha (98), in which all the petals save one are wanting; but such cases are very rare. To avoid this inaccuracy, De Candolle substitutes the term *gamopetalous*, meaning connected petals.

116. A petal is sometimes narrowed towards the base, appearing to consist of two parts, like the petiole and lamina of a leaf (*fig.* 72, *a.*). The narrow, stalk-like portion is the *unguis* or *claw;* and the spreading portion supported by the claw is the *lamina* or *limb.* The claws, adhering by their edges, form the *tube* of a monopetalous corolla (*fig.* 72, *b.*), and the spreading rims the *border.* The orifice of the tube is called the *faux* or *throat.*

Fig. 72.



A corolla is said to be *regular* when all the petals are nearly of the same form and size. When they are unequal in size, or cohere unequally, it is *irregular.*

117. The principal forms of a monopetalous corolla are: the *campanulate* or *bell-shaped* (*fig.* 72, *c.*), as in Campanula or Bell-flower, where there is no proper tube, the petals gradually diverging from the base to the summit; *infundibuliform* or *funnel-shaped*, as in Convolvulus (*fig.* 72, *d.*), which is like a bell-shaped corolla raised upon a tube, the petals being united quite to their tips; *hypocrateriform* or *salver-shaped* (*fig.* 72, *b.*), when the long tube has the limb spreading from it at right angles, as in Lilac, Phlox, &c.; and *rotate* or *wheel-shaped*, which may be viewed as a salver-shaped corolla with a very short tube, as in Lysimachia.

A *labiate* or *ringent* corolla (*fig.* 72, *e.*) results from the unequal cohesion of the petals, as in Monarda didyma and all Labiate plants; the two upper petals, cohering almost to their tips, form the upper lip, and the lower lip consisting of three petals similarly united.

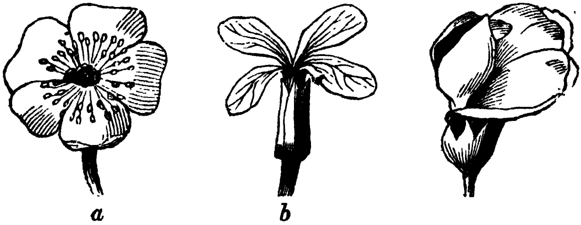
A singular modification of the labiate corolla exists in Teucrium or Germander, in which the two upper petals, instead of uniting with each other, cohere with the lower ones, the flower being thus destitute of an upper lip. When the upper lip is arched, as in Galeopsis or Hemp-nettle, it is sometimes termed the *galea* or *helmet.*

A truly labiate corólla always has the throat open. When a similar corolla has the throat closed by a projection of the lower lip, as in Snapdragon (*fig.* 72, *f.*), it is called *personate* or *masked*, and the portion of the lip closing the throat is named the *palate.*

118. A regular polypetalous corolla is said to be *rosaceous* (*fig.* 73, *a.*) when it consists of several (usually five) spreading petals, destitute of claws or with very short ones; as in the Rose and Apple. It is *liliaceous* when the petals are erect, gradually diverging from the centre, so as to resemble a bell-shaped flower. It is *caryophyllaceous* when there are five petals with long erect claws concealed within the calyx, as in the Pink (*fig.* 72, *a.*). When there are four petals of this kind the corolla is *cruciform* (*fig.* 73, *b.*); the four spreading limbs being placed opposite each other

in pairs, form as it were a cross. The Radish, Water-cress, and all Cruciferous plants, have this kind of corolla, from which the name of the tribe is derived.

Fig. 73.

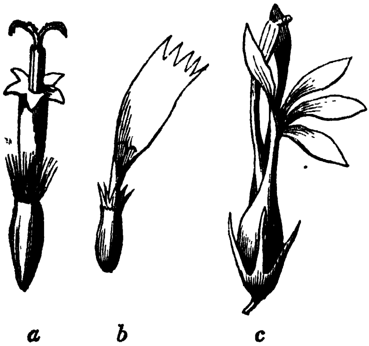


Among the various forms of irregular polypetalous corollas, only one has received a special name, viz. the *papilionaceous* corolla (*fig.* 73, *c.*), so called from a fancied but not very striking resemblance to a butterfly. It has five petals, of which the upper being larger than the others, covers them before the flower expands, and is called the *vexillum* or *standard;* the two lateral ones, parallel with each other, are the *alæ* or *wings;* and the two lower ones, usually cohering more or less by their lower margins, so as to appear like a single petal, form the *carina* or *keel.* Papilionaceous corollas are only found in the Pea tribe.

119. An *anthodium* (105) is usually called a compound flower, and on a superficial view the head of the Sun-flower or Coreopsis might be taken for a single flower; the involucre representing a calyx, and the flowers next the margin the petals of a polypetalous corolla, the smaller crowded flowers in the centre being often mistaken by careless observers for stamens or pistils. A little attention, however, shows that each of these are distinct flowers, provided for the most part, with a calyx, corolla, stamens, and pistils. The flowers of such a head are usually called *florets;* those of the centre are termed *florets of the disk* (*fig.* 74, *a.*), and exhibit a tubular corolla of five petals. Usually, those of the margin are larger and differently shaped from

the others, and are called *florets of the ray* (*fig*. 74, *b*,). These ray-florets have a monopetalous tubular corolla, like those of the disk, split down on one side nearly to the bottom, and spreading so as to form a flat surface. Such a corolla is termed *ligulate* or strap-shaped. If the student will compare the disk and ray-florets of a Coreopsis, or any other plant of the same tribe with the corolla of the Cardinal-flower (*Lobelia Cardinalis*, *fig*. 74, *c*.), he cannot fail to understand the structure of a ligulate corolla.

Fig. 74.



All the florets are ligulate in the Dandelion; and they are all tubular in Eupatorium, the Thistle, Centaurea, &c., none of which exhibit rays. Most commonly, however, the disk-florets are tubular and the marginal ones ligulate.

A flower destitute of corolla is said to be *apetalous*.

120. The corolla is frequently provided with certain appendages, which are in some cases mere prolongations of the petals, and in others an inner row of petals or modified stamens adhering to the corolla. Nearly all these appendages were included by Linnæus under the name of Nectary, whether they had any special power of secreting honey or not. Of the first kind is the *spur*, which in the Violet, Orchis, Snapdragon, &c., is a prolongation of the base of the lower petal. The petals of Silene have membranous scales growing from their upper surface just where the the claws expand into limbs; in this case they are said to be *crowned*, and the appendage is termed a *corona*. In Cynoglossum, or Hound's-tongue, the scales of the corona completely close the throat of the corolla. In Narcissus they grow

together, forming a cup within the petals, which in one species (the Daffodil) is as long as the true petals, exhibiting the appearance of an inner bell-shaped corolla.

At the base of each petal of the Ranunculus, there is a small honey-bearing spot or scale, usually called a nectary. Prof. Lindley suggests this scale to be a modified stamen united with the claw of the petal.

The spurs or horn-like bodies of the Columbine, Monkshood, and other plants of the same family, called nectaries by the older botanists, are true petals.

121. The corolla has been thought to be destined for the protection of the stamens and pistils during their growth; but that this is not its principal office is evident from the fact, that those organs are so far advanced as to need no special protection before the petals are large enough to protect them.

A few years ago M. Dunal advanced the idea, that the corolla is an apparatus for the conversion of the starch deposited about the base of the flower into sugar, for the nourishment of the anthers, pistils, and young seeds. It is well known that petals possess the power of producing honey, without the intervention of any special glandular apparatus. It bedews the tubes of most corollas, but is never found previously to the expansion of the flower, and its exposure to light and air. It is also well known that the disk (143) or receptacle of many flowers is filled with starch, which gradually disappears during the process of flowering. It was also remarked in another place (77), that petals even in sunshine deteriorate the atmosphere by taking away oxygen and returning an equal bulk of carbonic acid; now the same chemical change takes place when starch is converted into sugar. The theory of Dunal derives great plausibility from the ready explanation which it offers of these facts; it not only accounts for the action of petals in deteriorating the atmosphere, so different from that of leaves, and for the elevation of temperature which is sometimes observed (in some Arums especially) during the expansion of the flower, but also indicates a hitherto unsuspected analogy between flowering and germination; since in both processes a portion of carbon is converted into carbonic acid by means of the oxygen of the atmosphere, and starch is changed into sugar. The sugar thus produced by the corolla, is conveyed to the anthers and young seeds, forming as it were their appropriate food; and the honey which is so abundant in many flowers is an excretion of the superabundant portion.

The office of the calyx when it is colored and petal-like, is undoubtedly the same as that of the corolla: when green and leaf-like, its action upon the atmosphere is similar to that of ordinary leaves.

SECT. V. *Of the Stamens, or Fertilizing System.*

122. A STAMEN consists of two parts; the *anther* or pollen-case, and the *filament* or stalk upon which the anther is borne. Although generally present, the filament is no more essential to a stamen than the claw to a petal, or the petiole to a leaf. The number of the stamens varies in different plants, from one to several hundreds. Most frequently they are as numerous as the petals, or the petals and sepals taken together. If they are fewer than the pieces either of the calyx or corolla, we may be sure that a part of the true or normal number are transformed or abortive; if they are more numerous, the difference is owing to the development of one or more additional rows (98).

Nearly all Endogenous plants have either three or six stamens, and, although there are many exceptions to the rule, the number five or ten is most common in Exogenous plants. Even when they are very numerous, so as to be called indefinite, they are usually some high multiple of the primitive number.

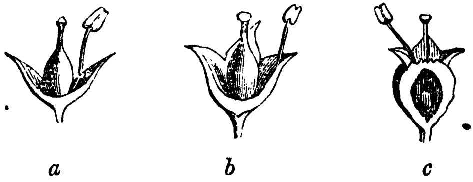
123. The stamens arise from the torus or receptacle of the flower (143), and occupy one or several rows between the base of the petals and the pistils. When they are equal in number to the petals, they are alternate with them; a circumstance which is in perfect accordance with the present views of the structure of the flower (98). Almost the only exception to this

rule is found in Primula and the whole Primrose tribe, in which the stamens are opposite the petals. To explain this anomaly, we are obliged to suppose that such flowers are normally provided with two whorls of stamens, of which the outermost is constantly undeveloped; and in confirmation of this view, in one plant of that tribe (Samolus Valerandi), the outer row makes its appearance in the form of five sterile filaments, alternating with the petals.

When two or more whorls of stamens are developed, they are commonly so much approximated as apparently to form a single row, but sometimes the second series may be detected by the difference in length. Thus, in Geranium, and Oxalis or Wood-Sorrel, there are ten stamens (or two whorls), of which five are considerably longest.

124. Although the stamens really arise in all cases from the torus just within the petals, yet they are exceedingly apt to contract adhesions with the organs in their vicinity; when, their true origin being obscured, they are said to arise from, or, in botanical language, to be *inserted* into, the calyx, corolla, &c., as the case may be. Thus, in almost all monopetalous flowers the stamens adhere for a part of their length to the tube of the corolla. In the Lilac the anthers seem to grow out of the corolla, the whole filament being inseparably united with the tube.

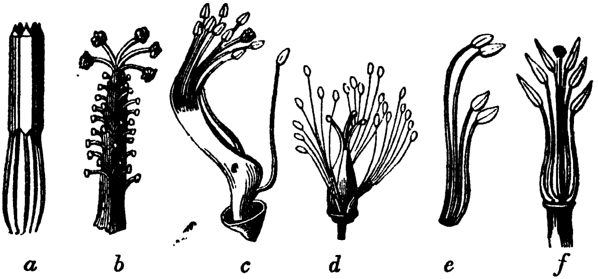
Fig. 75.



When the stamens contract no adhesion with neighboring organs, but surround the base of the pistil, they are said to be *hypogynous* (*fig.* 75, *a.*), or below the ovary. When they adhere by their bases to the tube of the calyx,* as in the Apple, Strawberry, &c., they are said to be *perigynous* (*fig.* 75, *b.*), or around the pistil. When the tube of the calyx is adherent to the ovary, the stamens are also carried up with it, and seem to arise from the top of the ovary ; as in all Umbelliferous plants. In this case they are said to be *epigynous* (*fig.* 75, *c.*), or upon the ovary. Sometimes the stamens adhere to the pistil beyond the calyx, forming a column with the style, as in the Cypripedium or Ladies'-slipper, and all the Orchis tribe. Plants with this unusual structure are called *gynandrous*, and the central body, consisting of filaments, anthers, styles, and stigmas, grown together into one mass, is called the *column*.

125. The stamens are occasionally connected with each other in various ways. In the great family of Compositæ or compound flowers, the anthers cohere into a ring, while the filaments are distinct, (*fig.* 76, *a.*) ; and in Lobelia, both the anthers and the upper half of the filaments are combined into a tube. When the anthers are thus united the stamens are said to be *syngenesious*. There are several families bearing flowers with the filaments united while the anthers are distinct. Thus, in the Mallow tribe, the filaments grow together for half their length or more, forming a cylinder which surrounds the pistils. In this case they are said to be *monadelphous* (*fig.* 76, *b.*), or to form a single brother-

Fig. 76.



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* Or, rather, to a membranous expansion of the torus lining the tube of the calyx.

hood. When they are joined in two sets or bundles, they are *diadelphous;* and this union takes place in several modes. Most of the Pea tribe have ten stamens, of which nine are united by their filaments into a single set, and one is free (*fig.* 76, *c.*); but in Æschynomene they are equally diadelphous, that is, combined into two sets of five stamens each. The stamens are diadelphous in Fumaria and Corydalis in a very singular manner; a good idea of which may be obtained by supposing four stamens to cohere into a tube, and then to be cleft quite to the base directly through two opposite stamens, so that each bundle consists of a perfect stamen in the centre with a half-stamen on each side.

When the bases of the filaments cohere in several sets, as in some Hypericums, the stamens are called *polyadelphous* (*fig.* 76, *d.*).

126. The stamens are usually of equal length or very nearly so, but in many flowers they are unequal. When there are four stamens, of which two are longer than the others, as in Snapdragon, and a great part of Labiate plants, they are said to be *didynamous* (*fig.* 76, *e.*). When there are six stamens, of which four are longer than the other two, as in Cabbage, Mustard, and all Cruciferous plants, they are termed *tetradynamous* (*fig.* 76, *f.*).

127. The filament or stalk of the stamen is usually a slender and thread-like or somewhat flattened body, having the same structure as the claw of a petal; that is, consisting of a bundle of spiral vessels with little or no woody fibre, surrounded by cellular tissue.

As has been already remarked (97), the filament is sometimes so much dilated that it can be distinguished from a petal only by the anther upon its summit. *Fig.* 77, *a*, represents one of the outermost stamens of the Water-lily in this condition. Occasionally the filament is slender below and much dilated towards the summit, as in Thalictrum clavatum (*fig.* 77, *b.*); while in Campanula and Chimaphila maculata (*fig.* 77, *c.*) the base is dilated into a fleshy scale. In some Cruciferous plants the filament is toothed or forked (*fig.* 77, *d.*). The filaments of Tradescantia or Spiderwort are very curiously tufted with long colored and jointed hairs (*fig.* 77, *e.*).

128. The *anther* is a little bag or receptacle of pollen, borne on the summit of the filament. It is joined to the filament in several ways. In the Lily and in all true Grasses the anther is fixed by its middle upon the apex of the filament, as on a pivot (*fig.* 78, *a.*), and in this case it is said to be *versatile.* Sometimes the base of the anther is firmly united with the summit of the filament, when it is said to be *erect*, or *innate* (*fig.* 77, *b.*, and 78, *b. c. d.*)

Fig. 77.

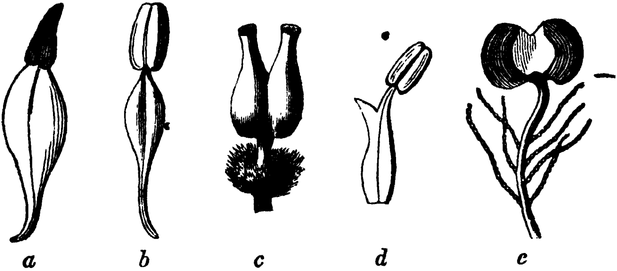
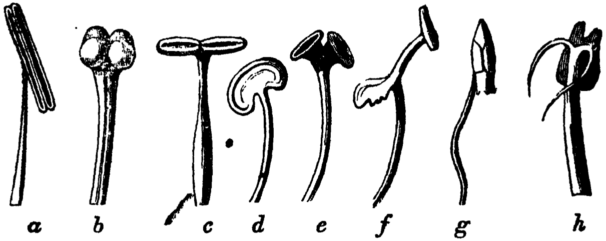


Fig. 78.



Sometimes its back adheres to the side of the filament, when it is said to be *adherent* or *adnate.* If the anther grows to the inside of the filament, it is said to be turned inwards, or *introrse*, as in the Pæony ; if it grows to the outside of the filament, it is said to be turned outwards, or *extrorse*, as in the Butter-cup and Anemone.

129. The anther usually consists of two oblong bags, called lobes or cells, held together by the *connectivum*, which is merely a prolongation of the filament; just as the midrib of a leaf is a continuation of the leaf-stalk. The form of the anther is subject to many variations, arising principally from the union or separation of its cells, and the shape of the connectivum. In Menispermum, or Moon-seed, each cell being deeply divided, the anther is *four-lobed* (*fig.* 78, *b.*). In other cases the two lobes grow into one, as in the Mallow tribe; and again in the Arrow-root tribe only one cell appears, the other one being abortive. It occasionally happens, also, that the anther-cells, instead of standing side by side, diverge from each other so that they might be mistaken for a one-celled anther placed across the top of the filament. This is the case in all the species of Monarda (*fig.* 78, *c.*); and the anthers of the Mallow, (*fig.* 78, *d.*), are similar, except that the two cells really grow into one by the union of their contiguous ends. In Justicia pedunculosa, the connectivum is forked, each fork bearing an anther-cell (*fig.* 78, *e.*); and in the Sage (*fig.* 78, *f.*), the long connectivum is placed across the filament, one end bearing an anther-cell, and the other usually having none at all. The slender horns of the anther in Violets, especially in Viola rostrata (*fig.* 78, *g.*), and the bristle-like appendages of Vaccinium and Andromeda (*fig.* 78, *h.*), are prolongations of the connectivum.

130. Each cell of the anther is usually marked with a line or furrow, running from top to bottom. This is the *suture* or *line of dehiscence*, by which, when the flower is fully expanded, the cells open, and the pollen falls out. The bursting of the anther at a determined period, is owing to the conversion of its cellular lining into a tissue of fibres, variously coiled or interwoven;* forming a multitude of little springs which

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* Purkinjé, *De cell. anther. fibrosis*; fide De Candolle, *Physiologie Végétale*, II., p. 534; and Mirbel, *Sur la structure de l'anthère et du pollen*, in *Recherches sur le Marchantia*, p. 55, et seq., pl. ix. f. 101, 102, 103, and 105.

mechanically force open the anther and push out the pollen. The coat of the anther is moreover very hygroscopic, contracting and rolling outward by dryness, so that it opens in dry weather only, at which time the pollen can best perform its office. Some anthers open by a transverse instead of a longitudinal line; but this is commonly owing to the divergence of the anther cells so that they touch each other by their lower ends only, as in *fig.* 78, *c. d.*, and thus the exception is rather apparent than real.

In the Potato, and also in all the Ericineæ or Heath tribe, the suture opens only by a little hole at the top of each cell, through which the pollen is discharged. The anther of Chimaphila maculata or spotted-leaved Wintergreen (*fig.* 77. *c.*) is a good illustration of this mode of opening. In the Barberry and the Sassafras, the anthers open by little valves hinged, as it were, at their upper edges; a mode peculiar to the respective tribes to which these plants belong.

131. The colored, powdery substance contained in the anther-cells is the *pollen.* Its office is to give life to the ovule or young seed. To the naked eye the pollen appears to be a fine powder, but when magnified sufficiently, it is found to consist of a multitude of little grains, the shape of which is perfectly similar in each plant, but widely different in different families. They are usually spherical or oval; but in the Teasel they are many-sided, in the Evening Primrose triangular (*fig.* 86.), and in the Spiderwort cylindrical. The surface is generally smooth, but is sometimes furnished with strong points or bristles.

In most plants the pollen is powder-like, but in Fuschia and the Evening Primrose the grains are loosely held together by a sort of web. In many Orchideæ, the grains cohere in threes and fours, and in others they all stick together, forming a solid, wax-like mass, which fills the anther-cell. Waxy pollen is also found in the Asclepias tribe.

132. The grains of pollen have two coats; the outer one is thick, somewhat fleshy and quite firm; the inner is an excessively delicate and very extensible membrane.

With an ordinary miscroscope, the contained matter seems to be merely a turbid fluid; but when submitted to a magnifying power equal to about 300 diameters, a great number of spherical or oblong particles are observed, all of which are in rapid and ceaseless motion on their axes. The largest of these particles are computed to be about the 5000th of an inch in diameter; the others are many times smaller.

The prevalent views as to the nature of these particles, together with the office of the pollen, will require notice after we have examined the structure of the pistil.

133. The reasons which induce us to believe that stamens are transformed leaves, much as they differ from those organs in appearance, have been noticed in another place (97). Assuming the correctness of this view, which no one who has properly investigated the structure of flowers will, we think, be inclined at the present day to dispute, it may be stated that the filament represents the claw of a petal, or which is the same thing, the petiole of a leaf. The filament is not an essential organ, but serves merely to support the anther, and, like the petiole or the claw of a petal, it is sometimes wanting. The anther is the transformed lamina of the leaf, the midrib being represented by the connectivum, the two sides are changed into anther-cells, and the margins are represented by the suture or line by which the cells usually open. That portion of the cellular tissue of a leaf which adjoins the cuticle is changed into a peculiar fibrous tissue, and the remainder is transformed into grains of pollen.

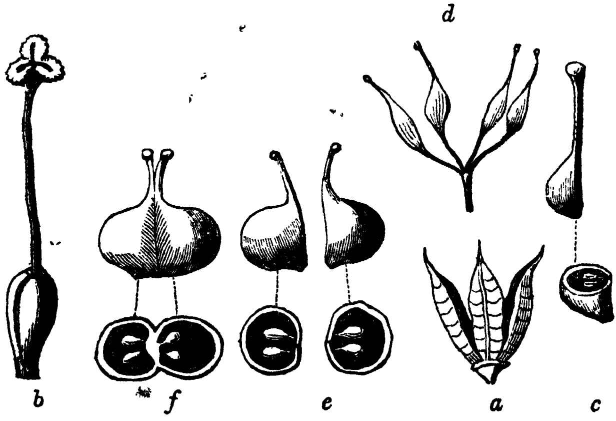
SECT. VI. *Of the Pistil or Fructifying System.*

134. The *Pistils*, or seed-bearing organs, (*fig.* 79), arise from the transformation of the uppermost whorl of modified leaves of which the flower is composed, and accordingly occupy the centre of the flower. The earlier botanists had no conception of their true origin and nature; thus, Linnæus supposed them to originate

from the pith, while the stamens he imagined to arise from the wood. It has been found impossible to explain, upon any principle, the varied forms which the pistil assumes, until the complete establishment of the theory of vegetable metamorphosis. To none of the floral organs does this theory apply more perfectly than to the pistil. By conceiving them to be transformed leaves, subject to the same laws of development as ordinary leaves, every thing relative to the position, connexion, and structure of pistils, and consequently of the fruit, is susceptible of an easy explanation.

There are usually several pistils in each flower: the normal number is undoubtedly the same as that of each row of the petals, sepals, &c., but the former are much more liable to have their original number reduced by suppression than the other floral organs. Thus the Pea and the Cherry have a single pistil, while the Columbine and the Larkspur (*fig.* 79, *a.*), have several in a single whorl, and those of the Ranunculus are still more numerous, forming several whorls. Solitary pistils are not, however, so common as is often supposed; for pistils like the sepals, petals, and stamens,

Fig. 79.



have a strong tendency to cohere with each other; as in the Lily, (*fig* 79, *b.*), where what appears at first view to be a single pistil, really consists of three united ones.

135. Each transformed leaf, or component part of the whorl (as in *fig*. 79, *a*, *d.*), is called a *carpel* or *simple pistil;* and when, as in the Lily (*fig*. 79, *b.*), *the carpels are combined into a single body, they* form a *compound pistil.*

That each carpel is a modified leaf is sufficiently evinced in the case of the monstrous Cherry, which we have already had occasion to notice (97, and *fig*. 63.). Here the carpel reverts to the state of a leaf, and sometimes a second one appears, the two being situated exactly opposite each other, like a pair of ordinary leaves. This interesting accident, if we may so call it, illustrates the manner in which the curious transformation of a leaf into a pistil is effected. The leaf is folded upwards, its superior surface becoming the inside, and its lower surface the outside of the carpel. All carpels are undoubtedly formed in the same method. The two lines or seams which we may commonly notice, one on the outer, and the other along the inner edge of each carpel, represent, the former the midrib of the fruit-bearing leaf, and the latter its united margins.

136. The inflated portion of the carpel (*fig*. 79, *c.*), which forms a case for the ovules or young seeds, is called the *ovary*, or by Linnæus the *germen.* This is the folded lamina of the leaf. Its apex usually tapers into a slender column (the *style*), the summit of which is commonly a little enlarged, forming the *stigma.* The appearance of the style is very variable, being sometimes very long and thread-like, and at others short and thick: in many cases it is wholly absent, being no more essential to a pistil than a petiole to a leaf, or a filament to a stamen. Both the stigma and the ovary, however, are always present.

The stigma is the only part of a plant (except the spongelets of the roots) which is destitute of cuticle. It opens directly into the tissue of the pistil and is therefore always moist in the living plant. We cannot here notice its various forms; sometimes it is a little round head, sometimes a minute point, and occasionally dilated and petal-like. In some cases it is smooth, in others hairy; sometimes the hairs are placed in several whorls around it, giving it the appearance of a bottle-brush (*aspergilliform*), as in many Grasses: in others it is *plumose*, or furnished with a double line of hairs like a feather.

The stalk of the carpel, representing the petiole, is generally wanting, yet it appears in several plants, as in Coptis or Gold-thread (*fig.* 79, *d.*). When present it is termed the *stipe* or support, or, more definitely, a *thecaphore* or pod-bearer.

137. The seeds, or as they are called in their early state, *ovules*, are always attached to the line representing the united margins of the leaf (*fig.* 79, *c.*), and never upon the outer seam, or midrib. It is conjectured that seeds are produced on the veinlets of the leaf projecting beyond the margins; but this is not susceptible of direct proof.

The seed-bearing seam of the carpel is commonly somewhat thickened, so as to project a little into the the cavity, increasing the surface for the attachment of the seeds. This line, consisting, as we have already remarked, of the united margins of the leaf turned inwards, is called the *placenta*. Often, indeed, it is not very apparent, but commonly it projects a little into the cavity of the ovary, in a few instances reaching quite to the opposite seam, dividing the cell into two compartments. These unusual cases excepted, a pistil made of a single leaf is always one-celled. A simple pistil also, can have but a single style and stigma, although the latter is occasionally lobed or partly divided.

138. All imaginable degrees of connection between carpels may be observed. In Asclepias and Apocynum the styles are coherent, the ovaries remaining separate; but this is unusual. In the Saxifrages the ovaries are commonly united at the base only. The common Nigella of gardens (*N. Damascena*) has

the ovaries perfectly coherent, while the styles are distinct; but in the Lily (*fig.* 79, *b.*) and in many other plants, the ovaries, styles, and stigmas are inseparably united.

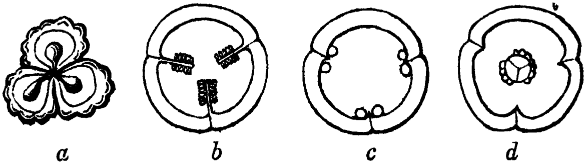
When the ovaries are unconnected or distinct (as in *fig.* 79, *a*, *c*, *d.*) they are said to be *apocarpous:* when they grow together forming a compound pistil, as in the Lily, the Poppy, &c., they are said to be *concrete* or *syncarpous.* These terms are of Greek derivation, meaning simply in the one that the fruit is separate, and in the other united.

139. We now proceed to consider pistils in a state of cohesion, beginning with the most simple form, the union of two carpels, which takes place more or less completely in nearly all Saxifrages. When there are two separate carpels in a flower they are so situated as to face each other by their seed-bearing or inner edges (as in *fig.*79, *e.*); and if their contiguous portions grow together, they produce a compound ovary of two cells, with the placentæ in the axis (*fig.* 79, *f.*) This arrangement results from the cohesion of two simple pistils. In the next place we may notice a compound pistil formed by the union of three simple pistils. The Tropæolum or common Nasturtium of gardens affords us a familiar example of this kind (*fig.* 80, *a.*), presenting a three-celled ovary resulting from the union of three carpels by their inner edges, the placentæ being in the axis as in the former example. When five, or a greater number of carpels grow together, the number of cells in the compound ovary will in each case equal the number of carpels of which it is composed, each cell being an ovary.

The partitions dividing the ovary into several cells, are called in botanical language *dissepiments;* they are evidently the sides of the carpels, or in other words, the inflexed margins of the leaves. Each dissepiment, it will be perceived, is necessarily double, although the two sides are often so intimately joined as to exhibit no trace of the union.

It is equally evident, that true dissepiments cannot be more numerous than the carpels themselves, neither can they divide an ovary horizontally. No transverse divisions, therefore, are true dissepiments. The pieces composing the walls or sides of a compound pistil, are usually termed *valves*. Thus the ovary of Hibiscus Syriacus (Althæa frutex of gardens) is five-valved and five-celled; and that of the Nasturtium is three-valved and three-celled.

Fig. 80.



140. Assuming the examples just referred to as the most simple kind, or type of compound pistils, we proceed to notice some deviations from the ordinary structure of very common occurrence, which, keeping in view the principles already deduced, will admit of an easy explanation. Suppose three carpels (*fig.* 60, *b.*), the sides of which are moderately folded inwards, yet not so as that their margins touch each other, to cohere into a single body. The result is a one-celled ovary of three valves or pieces, with three placentæ projecting into the cell, but not reaching to the centre so as to form partitions. In this case the placentæ are said to be *parietal* or attached to the walls of the ovary. The Poppy has an ovary of this kind, except that it is composed of more than three carpels. In the Orchis, the Blood-root, the Violet, &c. (*fig.* 80, *c.*), the edges of the carpels are not inflexed at all, but merely grow together, and the seeds therefore scarcely project into the cavity of the ovary; in these cases the placentæ are more strictly parietal than in the former case.

The Pink tribe presents an anomaly in the structure of the ovary, which, at first sight, is rather puzzling. The ovary, which consists of several carpels, is one-celled, and yet the placentæ are in the axis, forming what is called a *free central placenta* (*fig.* 80, *d.*). If we examine an ovary of this kind at an early period, the cause of the anomaly will be obvious. It is then divided into several cells, by very slender dissepiments reaching to the centre, where the thickened placentæ unite into a single spongy mass. The ovary, therefore, is originally constructed upon the ordinary plan, but its shell growing much faster than the partitions, the latter are stretched, and finally torn in pieces, scarcely a trace of them being observable in the full-grown ovary.

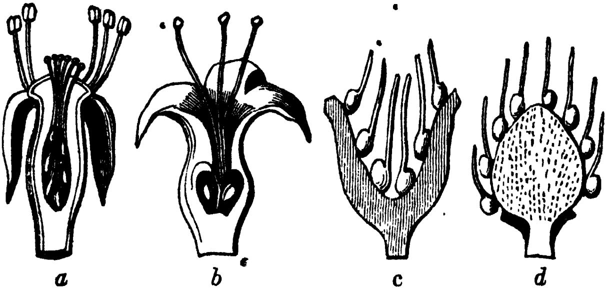
The student will occasionally meet with other anomalies; but by a recurrence to these first principles of the structure of pistils, little difficulty will attend their explanation. It must be borne in mind, that each organ is in all cases constructed on the same general plan, and, as Professor Lindley justly remarks, we have no right to infer that the simplicity of design so generally manifested in the works of nature, is departed from in those special cases, which we may be unable rightly to understand without due reflection.

141. In syncarpous ovaries (138) the styles are sometimes distinct, and in other cases united into a single column, which is often confounded with a simple style. When they grow together for a portion of their length, as in the Mallow, we commonly say that the style is *divided* or *cleft*. It will, however, be recollected that in this, as in other analogous instances, we continue to use these expressions for the sake of convenience only, meaning simply that the styles are only partially coherent. As each carpel or component part of a compound pistil has its own style, the number of the styles, or when these are entirely coherent of the stigmas, is usually a correct index of the number of carpels entering into the composition of such a pistil.

142. It has been observed (112) that the tube of the calyx sometimes grows to the surface of the ovary, carrying with it the petals and stamens, so that all these

organs seem to arise from the summit of the ovary. Instances of this kind are represented in *fig.* 71, *d*, *e*, *f*. Here the ovary is said to be *inferior*, which means the same as "calyx *superior* or *adherent*," and vice versa. The cup of the Rose very satisfactorily explains the manner in which ovaries become inferior, (*fig.* 81, *a.*). It is not, as at first sight it seems to be, a single inferior ovary, but an urn-shaped calyx-tube, investing a concave receptacle (143), to which a great number of separate carpels are attached; each carpel being furnished with its own style and stigma. These little ovaries might be mistaken for seeds, but seeds never bear styles. The principal difference between the pistils of a Strawberry and a Rose is that the receptacle of the one is convex, and of the other concave. *Fig.* 81, *c*, *d*, from Lindley, is intended to illustrate this. In the Strawberry (*d*) there are several rows of carpels arranged in the usual order, the innermost series occupying the summit of the receptacle; in the Rose (*c*), they are disposed in the same manner, except that exterior rows of carpels are carried above the innermost.

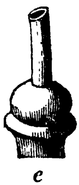
Fig. 81.



The ovaries of the Apple and Pear (*fig.* 81, *b.*), which are similar to those of the Rose, but are much fewer in number and usually contain two or more seeds, are slightly adherent by their inner edges, entirely surrounded by the juicy receptacle, and enclosed by the thickened and succulent calyx.

143. The *torus* or *receptacle* is the extremity of the peduncle, upon which the carpels and the other organs of the flower stand. It is not, therefore, a proper organ, although often spoken of as such. The apex of the peduncle is usually slightly enlarged to make room for the insertion of the pistils, the stamens, and the floral envelopes. Sometimes, however, it forms a fleshy ring surrounding the base of the pistil; as in the Orange (*fig.* 81, *e.*), when it is called a *disk*. In the Nelumbium, the top-shaped disk is furnished with a number of cavities, in which the carpels are half buried. In the Strawberry the receptacle is very much enlarged, having the carpels scattered over its surface; it at length becomes juicy, forming the delicious pulp which is commonly mistaken for the fruit of the plant. Often the receptacle elongates very much, forming a stalk for the pistils, as in Cleome; or for the pistil and stamens together, as in Gynandropsis, and, less manifestly, in many plants of the Pink tribe; or forming a slender axis on which several whorls of carpels are compactly aggregated, as in the cones of the Magnolia. In the Geranium the torus appears in the form of a slender beak, projecting far beyond the ovaries and cohering with the styles.

Fig. 81.



144. The rudiments of the future seeds, at their earliest appearance, are little pulpy excrescences of the placenta. These gradually increase in size, and about the time of the expansion of the flower, or a little previous to this period, have become regular-shaped, usually roundish bodies, fixed to the placenta by one side. These are termed *ovules:* they are ~~not yet seeds~~, but are destined to become seeds at a future period.

Ovules either stand directly on the face of the placenta, or upon the extremities of slender prolongations of that body; which are sometimes very short, but not uncommonly several times the length of the ovule, as in the Cockle (*Lychnis Githago.*) The seed-stalk receives the name of the *funiculus* or *podosperm.*

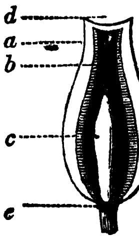
The number of the ovules varies greatly. There is but a single one in the ovary of the Peach, Cherry, &c.; and only one in each cell of the compound ovary of the

Tropæolum or garden Nasturtium. In other cases there are several, and often a great number, upon each placenta. When their number is uniform and not remarkably great, they are said to be *definite ;* but when it is variable, or, whether variable or constant, too great to be readily counted, the ovules are said to be *indefinite* in number.

As to the situation of the ovule within the cavity of the ovary, we may remark, that when the organ is attached to the bottom of the ovary, it is said to be *erect ;* if it be fixed to the placenta just above the base, as in the Apple, when it naturally takes an upward direction, it is termed *ascending.* In the Cherry it is suspended from the summit of the cell, and is said to be *pendulous.* Ovules are *horizontal*, when they project from the side of the cell, turning neither upwards or downwards; as in the Pea. The place by which the ovule joins the placenta is usually called its base, and the opposite extremity its apex. The determination of these two points, which is a matter of considerable consequence, would be quite easy were it not that most ovules during their growth either curve upon themselves, or are inverted upon their stalks; the apparent base and apex of the full-grown ovule and seed seldom corresponding with the true base and apex. We shall soon have occasion to return to this subject.

145. An ovule consists of a conical pulpy mass, termed the *nucleus*, invested by two coats or sacs. In *fig.* 82, *a* represents the outside covering, or, as it is called, the *primine ;* *b* the *secundine* or inner coat; and *c* the nucleus.

Fig. 82.



Mirbel has ascertained that, besides these coats, the nucleus has three coverings proper to itself, severally enclosing each other; but often only one, or at most two of these are distinguishable.

The primine and secundine do not entirely cover the nucleus, but leave at the apex a round hole, called the *foramen* (*fig.* 82, *d.*), which at a certain stage of growth is sometimes so large that it more nearly resembles the mouth of a goblet than a hole. It gradually contracts, closing up entirely when the ovule becomes a seed.

The nucleus and the two sacs have no organic connection with each other except at the base of the ovule, where vessels pass from one part to the other, and unite several parts quite firmly. This common point of union is termed the *chalaza* (*fig*. 82, *e*.). It is important to understand the true situation of the chalaza and foramen, since they furnish the key to the whole structure of the future seed. Their relative situation being determined by inspection, the internal structure of the ovule or seed may be inferred with certainty without dissection; the chalaza always indicating the real base, and the foramen the real apex of the ovule. It has moreover been ascertained by a great number of observations, that when the ovule becomes a seed, or in other words when an embryo plant is formed in its nucleus, the radicle or root of the rudimentary plant always points to the foramen, and the cotyledons (174) to the chalaza. Thus the one fact is the certain index of the other.

When the ovule preserves its original form (*fig*. 82.) throughout its growth, having a rectilinear axis with the chalaza next the placenta and the foramen at the opposite end, it is said to be straight or *orthotropous*. This is the primitive and most simple form of all ovules, although not of the most common occurrence. All the Cistineæ or Rock-rose tribe, and all the Nettle tribe, have orthotropous ovules.

Fig. 83.

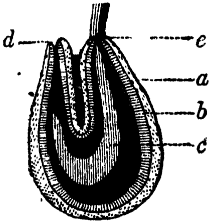
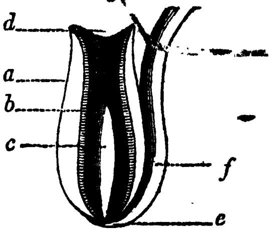


Fig. 84.



There are several families of plants in which, at an early period and from some unknown cause, the ovule curves round upon itself, the apex and the base being brought nearly into contact. (See *fig.* 83, in which the parts are lettered as in *fig.* 82.) Such ovules are said to be curved or *campulitropous;* and their axis is a curved line passing through the centre from *e* the base to *d* the apex.

The Pea tribe, the Pink tribe, and all Cruciferous plants have curved ovules.

There is a third modification which is the most common and also the most singular of all. In this kind the ovule, at a very early period, while yet a homogeneous mass, begins to grow more rapidly on one side than the other; consequently it is turned to one side, and finally inverted on the funiculus, so that its foramen or apex points to the placenta, the chalaza being at the opposite extremity. Ovules of this kind are said to be inverted or *anatropous.* Three points are to be observed in inverted ovules (*fig.* 84.), viz. *d*, the foramen, which indicates the true apex of the organ, looking towards although not connected with the placenta; *e*, the chalaza or true base of the ovule, having the apparent situation of the apex; and the *hilum* or point of attachment to the placenta, which is in this case quite distant from the chalaza.

In both straight and curved ovules the hilum and the chalaza are confluent with each other, or at least are separated only by the thickness of the primine (*fig.* 82 and 83, *e.*); but in inverted ovules they are separated usually by the whole length of the ovule. Among other characters, such ovules are recognised by the presence of a line or ridge passing from the hilum to the chalaza, called a *raphe* (*fig.* 84, *f.*). It is a cord of vessels destined to establish a communication between the chalaza and the placenta, being evidently nothing more than the upper portion of the funiculus adherent to the face of the ovule. Anatropous ovules exist in numerous families; those of the Apple, the Orange, the Violet, and especially of Viola (now Solea) concolor, are fine subjects for examination.

In the Primrose tribe, the funiculus adheres to the face of the ovule for about half its length only, and being accordingly suspended by its middle, with the foramen and chalaza pointing in each direction, it said to be *heterotropous.* It is plain, however, that this is no more than a modification of the anatropous form, the inversion being incomplete.

All ovules, and consequently all seeds, occur under some one of these three modifications. Each tribe or natural family uniformly exhibits one, and only one, of these forms; the structure of the ovule, consequently, furnishes excellent family characters. To avail ourselves of these characters is by no means a difficult task, although it requires an eye considerably practised in microscopical investigations.*

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* In this brief account of the structure of the ovule, it has been my object to present a condensed summary of the established facts, exclusive of minor details, and divested of all unnecessary technical language. I have purposely omitted all mention of the progress of discovery, and of the observations by which these facts were ascertained, as well as of the different terms employed in the descriptions of different writers. Our knowledge of the structure of the ovule and seed is of quite recent date. We are indebted for it, in every essential particular, to the investigations of two of the greatest—and in this department certainly the two greatest—botanists of this or any other age, viz. Brown and Mirbel. The observations of Brown are principally comprised in his "*Observations on the structure of the unimpregnated ovulum,*" appended to a paper on the genus Kingia, read before the Linnæan Society in the year 1825; but the same views are incidentally thrown out in several papers of earlier date. Those of Mirbel are published in two papers, read before the Academy of Sciences at Paris, in 1828 and 1829. I have wholly adopted his views, which are far more simple and satisfactory than those of any preceding writer. The descriptions of Brown are rendered unnecessarily complicated by assuming the point of apparent junction with the placenta (which in the seed is indicated by the hilum) as the true base of the ovule, while the chalaza is taken as the base of the secundine and nucleus. So, in an orthotropous ovule the base of the primine and of the secundine and nucleus are said to correspond; but in the anatropous form, the ovule as a whole is considered to be erect, and the secundine and nucleus inverted; or in other words, the base of the one coincides with the apex of the other. Thus when in the descriptions of those who adopt this view, the nucleus is said to be erect, the ovule is orthotropous; and when the nucleus is said to be inverted, the ovule is anatropous. The bases of the several parts of the ovule, however, are never disjoined, as this language seems to indicate.

SECT. VII. *Of Fertilization, or the action of the Pollen on the Pistil.*

146. We have said that ovules finally become seeds, but they are not merely ripened into seeds, the latter being something more than full-grown ovules. If the stigma be carefully protected so that no pollen fall upon it, although the ovules continue to grow until they attain their full size, yet they never become seeds. It usually happens, however, that a quantity of pollen does fall upon the stigma, and is retained by its glutinous surface: shortly afterwards a minute speck is discoverable in the nucleus, which becomes an embryo, or rudimentary plant; and the ovule then becomes a seed.

The ancients seem to have been vaguely acquainted with the office of the pollen, in several instances. The general fact, however, that the use of the stamens is to produce pollen, and that pollen falling upon the stigma gives life to the ovules, was first clearly and expressly stated by the English botanist Ray, in the year 1694; and thenceforth this fact, though sometimes disputed, was familiar to the botanists of those times. In 1735 the great Linnæus published his Fundamenta Botanica; in which he not only embodied the facts already known on the subject, but recorded many interesting observations of his own, establishing beyond contradiction the office of the stamens and pistils. We pass over the well-known and oft-repeated experiments by which these facts were demonstrated, as our object is only to present the the actual state of botanical knowledge, not to account for its origin, or trace its history.

147. Our attention may firstly be directed to the arrangements for securing the application of the pollen to the stigma. At the period when the flower expands, the anther-cells are closed, and the pollen is moist. Soon, however, the grains of pollen absorb into their interior the moisture of the cell, and the lining of the anther becoming dry, is rent into shreds and fibres (130); when the outer coat gives way at its suture, and the pollen falls out in the form of a dry powder.

The stigma at this period is bedewed with a clammy fluid, which serves to retain the grains of pollen that fall upon it; sometimes it is also provided with a tuft of hairs for brushing the pollen out of the anther-cells.

The relative position of the anthers and stigmas is generally such as to favor mechanically the application of the pollen to the latter. When the flowers are erect, the stamens are usually a little longer than the pistils; and when the former droop, the pistils are commonly longest; but many exceptions to this rule are known. The flowers of some species of Aloë, in which the pistil exceeds the stamens in length, are pendulous at the period of fertilization, although they are erect both previously and afterwards.* When the stamens and pistils are in separate flowers, the staminate flowers are commonly highest, as in Indian Corn and Typha or Cat-tail flag, so that a portion of the pollen must necessarily fall upon the stigmas. When this arrangement does not exist, as in many forest-trees, or where the stamens and pistils are borne upon separate plants, as in the Willow, Hemp, &c. the great abundance of pollen compensates for the less favorable position of the flowers. Insects in search of honey frequently brush the pollen upon the stigma, and thus aid in fertilization. Sir James Edward Smith maintained that the sole use of the honey of flowers, with respect to the plant, is to entice insects for this very purpose!

148. There are a few well-known instances in which fertilization is facilitated by certain special movements of the stamens. Thus, those of some Saxifrages, of Parnassia, and, still more strikingly, of the Rue, are one after the other inclined over the pistil when they give out their pollen. The stamens of the Barberry approach the pistil by a jerk whenever they are touched at the base on the inside; at the same time seldom failing to project a quantity of pollen upon the stigma. This remarkable instance of vegetable excitability was noticed in the preceding chapter (88). The same end is effected in the Kalmias or American Laurels by

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* De Candolle, *Physiologie Végétale*, II., *p.* 521.

means of a singular mechanical contrivance already noticed (65). These plants have erect flowers, and the stamens being considerably shorter than the pistils, it would seem that, apart from the aid which insects often afford, the fertilization of its ovules could only be brought about by some accident. Little, however, is left to chance in this instance. Previously to the expansion of the flower, the ten anthers are received into as many little pouches in the side of the monopetalous corolla, where they are secured by a viscid secretion. By the spreading of the corolla, the filaments are strongly curved outwards, remaining in that situation like so many springs until the anthers burst, and the pollen absorbs the glutinous matter which confines them; being the nliberated, they suddenly fly upwards with considerable force, throwing the pollen upon the stigma.

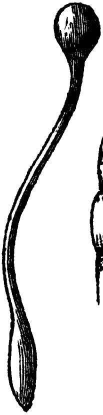
149. When grains of pollen are allowed to fall upon water, they absorb it rapidly and the grains burst. The office of the pollen, therefore, is liable to be frustrated by rain; long-continued wet weather at the time of flowering being, as husbandmen well know, very injurious to fruit-trees and crops of grain. This evil is, however, in a great degree guarded against by the property the anthers have of opening only in fine weather. So also when flowers are made to expand under water, their anthers contain no good pollen, and their pistils never perfect fruit.

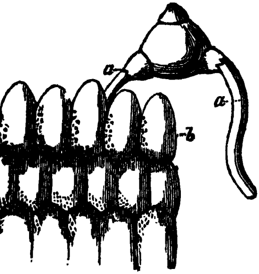
In this view the economy of various aquatic plants is extremely interesting. The Pond-weeds (*Potamogeton*) live entirely in the water, producing their flower-buds beneath its surface; but previously to the expansion of the flowers the peduncles elongate, and carry them above the water, so that the pistils are fertilized in the air. Soon afterwards they sink again, and ripen their seeds under water. The flower-stalks of the white Water-lily and Nelumbium, and the stems of the Water-shield (*Brasenia Hydropeltis*) sometimes attain the length of fifteen or twenty feet in our lakes and ponds, so as to bring the flowers to the surface, their length wholly depending on the depth of the water.

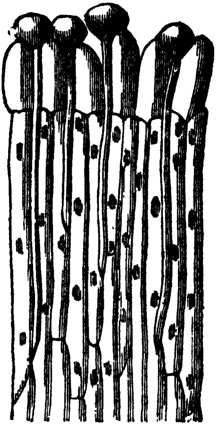
We must not pass over the curious mode of fertilization which Vallisneria presents, so often related both in prose and verse. This plant abounds in stagnant and slow-flowing waters both in Europe and North America; it is diœcious, that is, the staminate and pistillate flowers are borne on different individuals. The pistillate flower is supported by a long, very slender and spirally coiled flower-stalk. Just at the time when the flower is ready to expand, it is elevated to the surface by the uncoiling of the spiral flower-stalk. Meanwhile the staminate flowers are produced at the bottom of the pool, on short flower-stalks which are incapable of rising to the surface. The staminate flower-buds, therefore, break off from the peduncle, and rise in great numbers to the surface, where they expand and shed their pollen around the pistillate flower so abundantly as often to cover the whole surface of the pool. When the pistils are fertilized, their peduncles resume the spiral form, and draw the ovaries beneath the water, where the fruit is matured.

150. All our knowledge concerning the action of the pollen after it has reached the stigma, is of very recent date. Previously to the discovery of the remarkable facts which we are about to notice, no plausible account of the mode of fertilization had been given, if we except an attempt to avoid the difficulty altogether, by supposing that the matter contained in the pollen-grains gave an impulse to the stigma which extended to the ovules by a kind of sympathy. Of this hypothesis, which was for a long time prevalent, De Candolle remarks, that being altogether insusceptible of proof, it consequently has the merit of being little exposed to positive objections. The earliest observation calculated to throw light upon this hitherto mysterious subject, was made by Amici in the year 1823. While examining with his powerful microscope the pollen of a species of Purslane, which had remained some time upon the stigma, he discovered that several of the grains had projected from some point of their surface an extremely slender tube, like that repre-

sented in *fig.* 85, which is a highly-magnified grain of pollen with its tube.*







A few years afterwards, M. Adolphe Brongniart discovered these pollen-tubes in a great number of plants of different families; and his observations have since been confirmed and variously extended by Robert Brown, and other eminent botanists. These tubes are a prolongation, or rather a growth, of the inner coat of the pollen, filled with the fluid of the pollen-grains and the minute particles floating in it (132). They do not exceed the 1,500th of an inch in diameter, and of course can only be seen by the aid of powerful glasses. Usually they make their appearance only in pollen that has been for several hours applied to the stigma, pollen-grains thrown upon water bursting too suddenly and violently to allow of their production; but it is stated, that a liquid, composed of two parts of strong sulphuric acid and three of water, causes their production in the same manner as the stigmatic surface itself, but much more promptly.

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* From an observation of the late estimable Mr. Elliott (*Flora S. Car. and Georgia* I. p. 327), it appears that pollen-tubes were first detected by him in a single species (*Podostigma pubescens*), and traced from the anther quite to the ovary; but he seems not to have suspected their origin or use.

The grains of pollen having lain for some time on the humid stigma, open usually at a single point, but in several cases at two or more points of their surface; and their thin and highly extensible inner lining is slowly prolonged into a slender tube. These tubes sink into the lax tissue of the stigma, and gliding between the cellules and along the intercellular passages, pass down the style quite into the tissue of the placenta. Just at this period the curving of the ovules (145) is effected, by which (in the anatropous form) the apex of the ovule is brought in contact with the placenta; a communication being thus established between the pollen and the foramen of the ovule. There can be little doubt that the pollen-tubes themselves extend to the mouth of the ovule, and that one or more of the particles it contains are deposited in the nucleus. The pollen-tubes have in several instances been traced into the ovary; and that master-spirit in botany, Robert Brown, has more than once seen them inserted into the foramen of the ovules. M. Brongniart has also observed that those ovules, the apices of which are not bent down to the placenta, usually curve their stalks at the period of fertilization, so as to bring their mouths in contact with some portion of the placenta. Now, whether one of those curious active particles (132) contained in the pollen-grains is deposited in the nucleus of the ovule, and becomes the embryo plant; or whether the fluid of the pollen merely stimulates and gives life to an embryo already existing in the ovule, it is impossible for us to determine; neither is it probable that we shall ever possess the means of deciding the question.

Fig. 86, is intended to represent the manner in which the pollen of the common Evening Primrose (*Œnothera biennis*) acts upon the stigma; *a a* are pollen-tubes emitted from the angles of the grain of pollen, and *b* is the tissue of the stigma into which they penetrate. *Fig.* 87, represents the manner in which the pollen-tubes descend in the style of the Snapdragon. Both these figures are very highly magnified: they are taken from Lindley (*Introduction to Botany*), who borrows them from Brongniart.

In leaving this part of our subject, of which we have presented the merest outline, we refer the curious reader for further information, to those works and memoirs in which these remarkable facts are recorded. For an account of Professor Amici's investigations, see the 2d. and 21st. volumes of the *Annales des Sciences Naturelles*: the memoir of M. Brongniart is contained in the 12th. volume of the same work. Robert Brown's paper on the mode of fecundation in the Orchideæ and Asclepiadeæ, is contained in the Transactions of the Linnæan Society of London.

SECT. VIII. *Of the Fruit.*

151. The fertilization of the ovules being accomplished, and an embryo or miniature plant, or rather a minute body capable of growing into a plant, being formed in each, the pulp of the nucleus hardens, the integuments become firmer, the hole at the apex closes up, and the ovule is now called a *seed.* Meanwhile the ovary itself undergoes some changes, and the first to be remarked is its rapid increase in size. Sometimes the texture of the ovary remains nearly the same as at first; but it often becomes dry and leather-like, or crustaceous, or even woody; not unfrequently it is subject to a change of an opposite character, becoming first fleshy, and at length pulpy or juicy. The ovary is now termed the *pericarp* or *seed-vessel;* and this, with the seeds it encloses, constitutes the *fruit.* The term fruit has a more extensive signification in botanical, than in ordinary language. It is applied to the full-grown pistil whatever may be its size, form, or texture, and whether it be edible or otherwise. A grain of wheat or corn, or of the Sunflower or Thistle, is as truly a fruit as a peach, a gooseberry, or a melon.

The fruit, therefore, is not a new or distinct organ, but the fertilized pistil in a mature state. Its structure must accordingly be similar to that of the pistil; as it can have no organs or parts which did not exist, under some form in the fertilized ovary. It often happens, however, that parts which exist in the ovary are lost or suppressed in the fruit. Thus, to take some familiar examples, the ovary of the Oak has three cells, each cell containing two well-formed ovules; but in the acorn or ripened fruit there is uniformly a single cell and a solitary seed. In the ovary of the Chestnut, there are seven cells and fourteen ovules; the ripe chestnut has only one cell, filled by a single seed. Hence in one instance two cells and five ovules, and in the other seven cells and thirteen ovules are obliterated to make room for a single seed. In such cases, either all the seeds except one are destroyed by some unknown cause at an early stage of their growth; or, which is more probable, one seed (perhaps the one first fertilized) being more vigorous than the others, robs them of their share of nourishment, and thus causes them to perish; and as it increases in size, obliterating the adjoining cells by its pressure, it at length fills the whole cavity of the ovary. So constant and regular is this suppression, that whenever, as occasionally happens, an acorn or chestnut is found with three cells and several seeds, it is called a monster; whereas it is clear that the acorn or chestnut with a single seed which has strangled all its brethren in their infancy and grown large at their expense is the *real monster*. The same thing happens in the fruit of the Horse-chestnut, in which the suppression of several seeds and the obliteration of the cells may be most distinctly traced in all its stages. Such instances De Candolle appropriately terms *constant accidents*.

Occasionally the true structure of an ovary is masked in a different manner, the fruit seeming to be more complex than it really is. The simple one-celled pod of Astragalus becomes spuriously two-celled during its growth, by the turning inwards of the back of the carpel which comes in contact with the placentæ at the opposite side. In the Martynia, or Unicorn plant, a one-celled ovary with two parietal placentæ becomes a spuriously four-celled fruit; the partitions arising from the spreading lobes of the placentæ adhering to the walls of the seed-vessel. So, likewise, the two-celled fruit of the Thorn-apple (*Datura Stramonium*) appears to be incompletely four-celled, but an inspection of the ovary reveals the true structure of the fruit. These examples are sufficient to show the importance of examining the ovary, whenever we are in any doubt as to the true nature of a fruit.

152. The transformation of a leaf into a petal, a stamen, or a pistil, is not more extraordinary than the changes it undergoes when the pistil is changed into a fruit. In some cases, the ovary grows into a fleshy body, which gradually changes into an agreable pulp, as in the grape. Sometimes it is transformed into a bony nut, as in the hazel-nut, the Cocoa-nut, &c.; and in other cases it becomes in part a hard and dry body like a nut, and in part a delicious pulp; as in the plum and peach.

Such transformations are not necessary to the existence of fruits, many of which preserve nearly the ordinary texture of leaves: neither are they confined to seed-vessels; for in more cases than is usually supposed, other modifications of leaves, and even stems, undergo the same changes. Thus, to notice a few examples out of many, the calyx changes into a crustaceous body in Salsola and Spinage; it is greatly thickened, red and juicy in the Strawberry-Blite, and pulpy and agreeably-tasted in the Wintergreen (*Gaultheria*); being in both instances commonly mistaken for the fruit, from which it is wholly distinct. Nearly the whole bulk of the apple is a thickened calyx. In the Yew, the bracts become pulpy and berry-like; the flesh of the Bread-fruit (*Artocarpus incisa*) results from the thickening of all the floral envelopes of a large head of flowers, and their union into a single compact mass; and lastly, the delicious pulp of the strawberry is the enlarged and juicy extremity of the flower-stalk! We might easily multiply examples, proving that every organ of vegetables is subject to all the transformations which we are apt to suppose peculiar to the fruit.

The process of fruiting, moreover, is not more difficult to understand, nor indeed is it very dissimilar to the accumulation of starch in the Potato, or the formation of sugar in the roots of Beets, the stem of the Sugar-cane, or the corolla of flowers.

153. Those fruits which preserve a green color and leaf-like texture during their growth, as the pods of Peas and Beans, are furnished with breathing-pores like true leaves: they receive the ascending sap, part with its superfluous water by evaporation, affecting the atmosphere in the same manner as ordinary leaves. If, however, the quantity of parenchyma diminishes, that of the lignin increasing either absolutely or relatively, the seed-vessel loses its green color, and becomes dry and parchment-like, or crustaceous, or even bony; in which cases it no longer receives the ascending sap, or produces any effect whatever on the surrounding atmosphere.

The fruits which become fleshy or juicy, may be supposed to acquire that state in the same manner as the stems and leaves in the Cacti or Prickly-pear tribe, the Ice plant, &c. Their cellules, filled with elaborated sap which abounds with mucilage, jelly, &c., form an endosmometric apparatus (65), attracting the ascending sap by virtue of the greater density of the contained fluid. The stomata are mostly closed to guard against excessive evaporation, and a large quantity of water is solidified by combining with the tissue of the fruit. Such fruits, however, continue to evaporate slowly, and while their green color remains they affect the atmosphere just like true leaves, except when their constituents are undergoing certain chemical changes. Thus, when grapes become sour they abstract oxygen from the atmosphere, but when in ripening they become sweet, they restore to the air even a greater amount of oxygen than they had previously absorbed from it.

The various colors which the surface of fruits assume during their growth are probably owing to certain changes of the chromule, analogous to what takes place in leaves just before their fall.

154. The process of ripening consists in certain chemical changes or reactions, to which the accumulated products are subject under the influence of air, light, and especially of a proper temperature. That it is not owing to the acquisition of new materials, is evident from the well-known fact, that nearly all full-grown fruits are capable of ripening when separated from the stem. This was also demonstrated in the most striking manner by M. Tschudy,* who succeeded in grafting young melons upon gourds, and the fruit of the Tomato upon the stem of a Potato; the fruits grew and ripened, preserving their own peculiar flavor unaffected by the stock. When ripening commences, the acid of the fruit usually increases in quantity, and in cherries and currants it continues to increase until the fruit is matured. In other edible fruits the acid after a time diminishes, and the quantity of sugar rapidly increases. The sugar is formed by the action of the vegetable acid on the gummy, gelatinous, and woody matters, which are very susceptible of being changed into sugar (80). Thus, M. Couverchel found that if apple-jelly be treated with acid we obtain a kind of sugar resembling that of grapes; that the gum of peas mixed with oxalic acid is converted into sugar by heat; that the gum extracted from starch renders the juice of green grapes sweet; and that tartaric acid produces the same effect by the aid of heat; suggesting the reason why most fruits become sweet when cooked.†

Fruits will not ripen in air containing no oxygen; which by combining with the excess of carbon enables the constituents of the fruit to undergo the necessary changes. So, if fruits be plucked just before they ripen, and placed in an atmosphere free from oxygen, they may be preserved for a very considerable time in that state, and when again exposed to the air, they ripen as well as before. Ripe fruits, also, do not decay in the absence of oxygen, but after some time they undergo other changes.

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* *Essai sur la greffe, &c.*, De Candolle, *Physiologie Végétale.*

† De Candolle, *Physiologie Végétale*, II., p. 586.

155. As the pericarp or seed-vessel is nothing but the matured ovary, its structure must be the same as that of the pistil from which it results; the principal differences between the young and the ripened ovary, apart from the increased bulk of the latter, consisting, as has been already observed, not in the production of any new tissue, but in the disproportionate growth, or annihilation, of some previously existing parts, and in certain changes of their texture. When an ovary is cut across we commonly observe that its walls are composed of three more or less distinct parts, viz.: an outer and an inner lining, and an intermediate fleshy or pulpy portion. If the pistil be a transformed leaf, the inference is unavoidable that these parts correspond respectively with the cuticle of the upper and lower surface, and its intermediate green pulp or parenchyma. In many seed-vessels the intermediate portion wholly disappears, and the inner and outer coats are inseparably joined, apparently forming a single membrane: this is similar to the change which takes place when leaves are transformed into scales, as in the covering of buds (43). It more frequently happens, however, that these portions are more distinct as the ovary advances to maturity, and it becomes necessary to distinguish them by separate names. The exterior coat is therefore termed the *epicarp;* the inner lining, the *endocarp*, or oftener as it forms the flesh of the fruit, the *sarcocarp*. Thus in the peach, the stone (consisting of the cuticle combined with the denser parenchyma of the upper surface of the leaf (*fig.* 37), all in an indurated state) is the endocarp; the pulp (the enlarged and softened parenchyma of the lower side of the leaf) the sarcocarp; and the skin or outer covering, is the epicarp. It is in fleshy fruits only, that these several parts are so remarkably distinct. In dry fruits, such as pods and capsules, the thin sarcocarp usually grows firmly to the endocarp or epicarp, the walls apparently consisting of two portions only.

156. After the ripening of fleshy fruits and the maturation of their seeds, they usually separate from the peduncle, falling to the ground entire; and in due time, when the seeds grow, they find an abundant supply of

nourishment in the decaying flesh of the pericarp. Many dry fruits, such as nuts, also fall to the ground entire, the firm pericarp serving as an additional covering to the seeds until they begin to grow, when being no longer needed for their protection, it either opens in some way, or decays. Both these kinds of fruit, being closed throughout the whole term of their existence, are said to be *indehiscent*. When, on the other hand, a pericarp splits open or falls in pieces, allowing the ripe seeds to disperse, it is said to be *dehiscent*.

157. The mode in which the dehiscence or bursting of seed-vessels occurs, is easily understood by a recurrence to the structure of the pistil. We commence with the most simple case; that of a fruit formed of a single carpel. Such a fruit is commonly more or less two-edged; the outer edge representing the midrib, and the inner one the united margins of the folded leaf (*fig*. 88). If the fruit be dehiscent, it opens at maturity along one or both of these edges, which, for this reason, are called *seams* or *sutures*. That occupying the place of the midrib, or the back of the leaf, is termed the *dorsal* suture (*fig*. 88, *d*.); the other resulting from the union of its margins, is exactly opposite the first (*fig*. 88, *v*.), and is called the *inner* or *ventral* suture. To the latter the seeds are always attached in simple fruits.

Fig. 88.

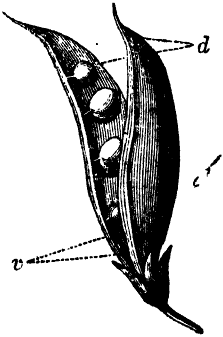


Fig. 89.

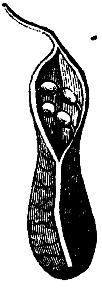
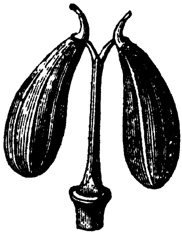


Fig. 90.



When such a pericarp becomes old and dry, the most natural mode of dehiscence would seem to be by the inner suture, which opens merely by the disruption of the united margins. This happens in the Larkspur (*fig*. 89), and in all follicles. In other cases both sutures open, as in the pod of the Pea, and all Leguminous plants. In a very few instances, as in Magnolia, the dorsal suture opens, the inner remaining closed All dehiscent simple fruits open in some one of these modes.

158. We proceed, in the next place, to examine the dehiscence of a compound fruit; that is of a fruit formed by the union of several carpels. It is most natural to suppose that a body composed of several, say of five, carpels cohering by their sides, should fall in pieces when ripe, at the points of union, the carpels becoming again distinct. This happens in Kalmia, Rhododendron, &c.; and is illustrated in *fig*. 91, which exhibits such a fruit after it has opened; the annexed diagram, (*fig*. 92,) representing a transverse section of the same. Here the dehiscence taking place through the dissepiments, is said be *septicidal;* that is, to cut through the partitions.

Fig. 91.

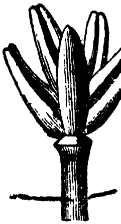
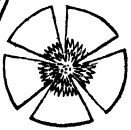


Fig. 92.



A body called the *columella* or *axis*, is sometimes left in the centre of the fruit; consisting either of the united placentæ of the several carpels, as in Rhodendron, &c., or of a prolongation of the torus to which the carpels were joined, as is seen in *fig*. 90.

This kind of dehiscence merely separates the several carpels from their connection with one another; each of which may remain closed as in Umbelliferous plants (*fig*. 90), or may open by their inner suture as in Rhododendron (*fig*. 91), or occasionally by both sutures. In the Euphorbias, and the Castor-oil plant, the splitting continues to the fullest extent; the three carpels in the first place separating from one another by a septicidal dehiscence, each opening by its inner suture: soon after, the dorsal suture also gives way, and lastly, each piece splits into two, by the separation of the endocarp from the epicarp.

159. When the several carpels of which a compound fruit consists, are more intimately united, it often happens that the dorsal suture of each carpel gives way, thus effecting an opening into each cell. This is *loculicidal* dehiscence. *Fig.* 93, exhibits it in the two-celled fruit of the Lilac, and *fig.* 94, in the three-celled fruit of the Martagon Lily. The annexed diagram (*fig.* 95,) of a transverse section of the capsule of Hibiscus, illustrates the same dehiscence in a five-celled fruit. Each valve, or piece into which the seed-vessel separates, has a portion of the dissepiment attached to its middle, a circumstance which was quite puzzling before the structure of such a fruit was fully understood. All difficulty vanishes when we view each piece, not as a single carpel, but as two half-carpels joined together, the dissepiment being formed of the united and inflexed margins of two contiguous transformed leaves.

Fig. 93.

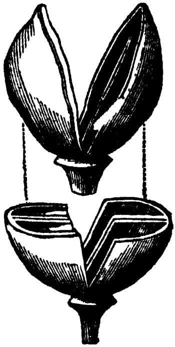
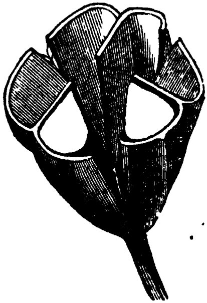


Fig. 94.



160. The kind of dehiscence just described is sometimes modified by the separation of the valves from the dissepiments, forming what is sometimes termed *septifragal* dehiscence. A convenient example oc-

curs in the Convolvulus or Morning-glory in which the valves fall away leaving the partitions upon the receptacle (*fig.* 96). In like manner, the two valves separate from the placentæ in such one-celled fruits, as those of Sanguinaria and Corydalis.

Fig. 95.

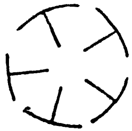
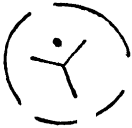


Fig. 96.



All cases of true dehiscence may be reduced to some one of the above mentioned forms; a little attention enabling us to explain the occasional anomalies that occur. Thus, in the Chickweeds and other plants of the Pink tribe, the sutures give way only at the apex of the seed-vessel, which is said to open by teeth (*fig.* 97.) The fruit of the Poppy discharges its seeds through little holes appearing just beneath the corners of the shield-shaped compound stigma. These holes are weak points of the sutures, over which the angles of the stigma are so accurately adjusted that they do not appear until this body, becoming hard and dry, curves upwards and leaves them exposed.

161. In several instances a seed-vessel opens by a transverse circular line following no sutures whatever, but cutting directly across them. This is called *circumscissile dehiscence ;* but is an anomaly, and not a true dehiscence as we have employed the term: it takes place with great regularity in Anagallis and a few other plants, the upper part of the seed-vessel separating evenly from the lower, like the cover of a box (*fig.* 98.). A fruit of this kind is sometimes termed a *pyxidium ;* that is, a little chest.

Fig. 97.

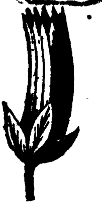
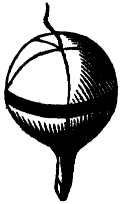


Fig. 98.



The fruit of Jeffersonia is a pyxidium opening only half-way round.

Some pods, instead of opening by sutures, separate transversely into several pieces when they become old, as in *fig.* 99.; this, also, is not a case of genuine dehiscence.

In a few cases the walls of the seed-vessel are broken through, ragged holes being formed, as if by great and irregular distention. The weakest part of the pericarp always gives way in these instances, and the bursting is effected with considerable uniformity. Thus the fruit of Campanula or Bell-flower is torn open near the base, while that of the Snapdragon bursts at the summit.

162. We have given, as much in detail as our present plan will admit, the principal facts relative to the structure of fruits, and the circumstances from which their most remarkable modifications arise. Their diversities of form and structure are more numerous than those of any other organ whatever. They are all, however, reducible to a few simple forms, and the application of the principles already laid down will readily explain all their varieties. We shall close this section with a passing notice of the several kinds of fruits which have received special names, admitting only those of common occurrence in works of descriptive botany.

Several celebrated botanists have contrived classifications of fruits, defining all the possible varieties with great precision. To the accomplished systematic botanist, these minute arrangements are indispensable; yet, to avoid burdening the memory of the student with a great number of terms not in ordinary use, I have refrained from fully adopting any of these methodical arrangements.[*]

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[*] The principal modern classifications of fruits which have attracted any considerable attention among botanists, are those of Richard, Mirbel, Desvaux, and Lindley. For the convenience of botanical students to whom the works of these authors are not accessible, I subjoin an abstract of the latest and best of these arrangements, viz. that of Professor Lindley. I have substituted other examples in place of the original ones whenever more familiar illustrations could be drawn from well-known North American plants.

CLASS I. SIMPLE OR APOCARPOUS FRUITS.

Ovaries strictly simple; only a single series produced by a single

1. UTRICULUS: a one-celled, one or few-seeded, superior fruit, with a membranous pericarp, frequently dehiscent by a transverse incision.

Examples. Amaranthus, Chenopodium.

163. We may commence our enumeration with any of the fruits formed of a single carpel; the follicle, however, is usually taken as the type of SIMPLE FRUITS.

The *Follicle* (*fig.* 89.) is a ripened carpel, opening by its inner suture only. The carpels represented in *fig.* 79, *a*, *c*, *d*, all become follicles in fruit. Some kinds of Larkspur bear solitary follicles, but generally several are produced in each flower, as also in the Columbine

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2. ACHENIUM: a one-celled, one-seeded superior fruit, with a hard and dry indehiscent pericarp, not adhering to the integuments of the seed. Such fruits were considered by Linnæus as naked seeds with a bony covering; they are by some authors called *nuts*.

Examples. Lithospermum, Onosmodium.

3. DRUPA: a one-celled, one or two-seeded, superior indehiscent fruit; the outer coat of which is soft and fleshy, and separable from the inner or *endocarp* (the stone), which is hard and bony.—The stone of this kind of fruit is called a *nut* by Richard.

Examples. Peach, Plum, Apricot.

4. FOLLICULUS: a one-valved, one-celled, one or many-seeded, superior fruit; dehiscent by its ventral or seed-bearing suture only.

Examples. Pæonia, Delphinium, Caltha.

5. LEGUMEN: a one-celled, one or many-seeded, two-valved, superior fruit; dehiscent by its dorsal and ventral suture, bearing seeds along both margins of the latter. A legume differs in nothing from a *follicle* except in dehiscing by both sutures. Sometimes it is indehiscent; but the sutures indicate the line of dehiscence.

Examples. Bean, Pea, Clover.

6. LOMENTUM: an indehiscent legume, contracted between each seed, and at maturity separating at the contracted portions into distinct pieces.

Examples. Desmodium, Hedysarum.

CLASS II. AGGREGATE FRUITS.

Ovaries strictly simple; more than a single series produced by each flower.

7. ETÆRIO: ovaries (achenia) distinct and indehiscent; either dry upon a dry receptacle, as Ranunculus; dry upon a fleshy receptacle, as Strawberry; or fleshy upon a dry receptacle, as Rubus.

Examples. Ranunculus, Fragaria, Rubus.

8. SYNCARPIUM: ovaries cohering into a solid mass upon a slender receptacle.

Examples. Magnolia, Asimina.

(*Aquilegia*), the Gold-thread (*Coptis trifolia*), the Pæony, &c.

A *Legume* or pod (*fig.* 88.) differs from a follicle only in opening along both sutures: the pods of the Pea and Bean are familiar examples. This kind of fruit is universal in plants of the Pea tribe, which are accordingly termed Leguminosæ, or Leguminous plants. The legume exhibits several modifications. Although it has two well-formed sutures, sometimes it does not open by either, but the sides falling off from

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9. Cynarrhodum: ovaries (achenia) inclosed within the fleshy tube of a calyx.

Examples. Rosa, Calycanthus.

Class III. Compound Fruits.

Ovaries formed of two or more united carpels.

Sect. I. Fruit superior.

A. *Pericarp dry.*

10. Caryopsis: a one-celled, one-seeded, dry and indehiscent, superior fruit; the *endocarp* cohering inseparably with the integuments of the seed, so that the two are undistinguishable.—The ovary if compound in such fruits is only known to be so by the presence of two or more stigmas.

Examples. Wheat and all Grasses.

11. Regma: a few-seeded, superior, dry, three-(or more) celled fruit, the cells (*cocci*) bursting from the axis elastically, and separating into two valves.

Examples. Euphorbia, the Castor-oil plant, &c.

12. Carcerulus: a many-celled, superior fruit; the cells dry, indehiscent, and few-seeded, cohering by a common style around a common axis.

Examples. Malva, Tropæolum.

13. Samara: a two or more celled, dry, superior fruit: the cells indehiscent, and dilated into wing-like expansions.

Examples. The Ash, the Maple, and the Elm.

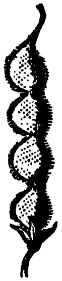
14. Pyxidium: a one celled, many seeded, superior fruit; with a dry, often thin, pericarp, dehiscent by a transverse incision.

Examples. Anagalis, Portulacca, Plantago.

15. Conceptaculum: an elongated, two-celled, many-seeded, superior fruit, separating into two portions; the seeds not adhering to marginal placentæ, as in the follicle which it closely approaches, but

the sutures, leave a kind of frame, termed the *replum*. In other cases the legume is not dehiscent at all.

Fig. 99.



An indehiscent legume is sometimes divided into several cells by false horizontal partitions arising from the pericarp, as in some Cassias; or by contractions of the legume itself, as in Desmodium (*fig*. 99.): the latter fruit when ripe, falls into pieces at each of these joints; it is called a *loment*.

A legume is sometimes both indehiscent and one-seeded, as in the Clover, and then it resembles an achenium.

An *Achenium* or grain (*fig*. 100 and *fig*. 101.) is a ripened one-seeded carpel, with a dry and indehiscent pericarp, having no appearance of a

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separate from their placentæ, and lying loose in the cavity of each cell. (?)

Examples. Asclepias, Echites.

16. Siliqua: an elongated, two-celled, many-seeded, superior fruit; dehiscent by one or two valves, separating from the replum; the seeds being attached to two placentæ adhering to the replum, and *opposite* to the lobes of the stigma.—Sometimes the placentæ do not meet in the centre, and then the silique is imperfectly two-celled.

Examples. Radish, Mustard, &c.

17. Silicula: a short, and usually few-seeded siliqua.

Examples. Lepidium, Capsella.

18. Ceratium: a linear, one-celled, many-seeded, superior fruit; dehiscent by two valves, separating from the replum; with the seeds attached to two spongy placentæ adhering to the replum, and *alternate* with the lobes of the stigma.—This fruit, which is sometimes called a siliqu-form capsule, differs from a stigma with an imperfect partition in the lobes of the stigma being alternate with the placentæ, instead of opposite.

Examples. Sanguinaria, Chelidonium, Corydalis.

19. Capsula: a one or many-celled, many-seeded, superior, and dry fruit; always proceeding from a compound pistil, and dehiscent by valves.

Examples. Digitalis, Datura, Viola.

20. Amphisarca: a many-celled, many seeded, superior, indehiscent fruit, indurated or woody externally, and pulpy internally.

Example. Adansonia.

suture. The matured ovaries of the Ranunculus (*fig.* 100.), of the Rose and of Clematis or Virgin's-bower (*fig.* 101.) are achenia. In the latter instance the style, furnished with a plume of hairs, remains upon the ripe fruit.

Fig. 100.

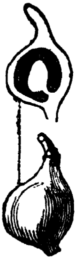
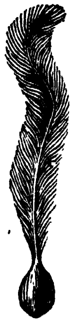


Fig. 101.



By the elder botanists, these and similar fruits are called naked seeds. They resemble seeds in size and appearance: but, saving a few remarkable exceptions hereafter to be noticed, all seeds are enclosed within seed-vessels. On cutting open an achenium we observe the real seed lying loose in the cell, which it partly or entirely fills (*fig.* 100,).

B. *Pericarp fleshy.*

21. **Tryma**: a superior fruit, by abortion one-celled and one-seeded; with a two-valved indehiscent endocarp, and a coriaceous or fleshy sarcocarp.

Examples. Juglans, Carya.

22. **Nuculanium**: a two or more celled, few or many-seeded, superior, indehiscent fruit, fleshy and of the same texture throughout.—Differs from the berry only in being superior.

Examples. Grape, Solanum.

23. **Hesperidium**: a many-celled, few-seeded, superior, indehiscent fruit, covered by a spongy separable rind; the cells easily separable from each other, containing a mass of pulp in which the seeds are imbedded.

Examples. Orange, Lemon.

Sect. II. Fruit inferior.

A. *Pericarp dry.*

24. **Glans**: a one-celled, one or few-seeded, hard and dry, indehiscent fruit, seated in a cupule; proceeding from an ovary of several cells and several seeds, all of which are abortive but one or two.

Examples. Quercus, Castanea, Fagus.

25. **Cypsela**: an achenium invested with the membranous tube of the calyx.

Examples. All Compositæ.

A seed furnished with a style is a manifest absurdity; yet all these *pseudospermic* or seed-like fruits show on some part of their surface, either the hardened base of the style (so conspicuous in the fruits of many Cyperaceæ, as in *fig*. 62, *g*.), or a scar, indicating the place from which it has fallen. Not unfrequently the whole style is persistent on the fruit, as in Clematis just referred to (*fig*. 101.).

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26. Cremocarpium : a 2-5-celled, inferior fruit; the cells dry and indehiscent; when ripe separting from a common axis.

Examples. Umbelliferæ, Aralia, Galium.

27. Diplotegia : a capsule invested with a membranous calyx-tube.

Examples. Campanula, Lobelia.

B. *Pericarp fleshy.*

28. Pomum : a fruit formed of several cartilaginous or bony, few-seeded ovaries, sometimes slightly united with each other, invested by a thick and fleshy calyx.

Examples. Apple, Cratægus, Amelanchier.

29. Pepo : a one-celled, many-seeded, inferior and indehiscent, fleshy fruit; with the seeds attached to parietal pulpy placentæ.

Examples. Cucumber, Melon, Gourd.

30. Bacca : a many-celled, many-seeded, inferior, indehiscent, and pulpy fruit; the attachment of the seeds lost at maturity, when they become scattered in the substance of the pulp.

Examples. Currant, Gooseberry.

31. Balausta : a many-celled, many-seeded, inferior, indehiscent fruit; the seeds with a pulpy coat, distinctly attached to their placentæ.

Example. Pomegranate.

Class IV. Collective Fruits.

Fruits of which the principal characters are derived from the thickened floral envelopes.

32. Diclesium : an indehiscent, one-seeded pericarp enclosed within an indurated perianth.

Examples. Mirabilis, Salsola.

33. Sphalerocarpum : an indehiscent, one-seeded pericarp, enclosed within a fleshy perianth.

Examples. Taxus. Blitum.

The fruits of the Sunflower and all Compositæ are achenia,* invested with a membranous calyx-tube, which is inseparably united with the surface of the seed-vessel (110, and *fig.* 71, *e*, *f*.).

The fruit of Umbelliferous plants (*fig.* 90.), sometimes called a *cremocarp*, consists of two such achenia placed side by side. Two or four ordinary achenia, with their styles united, compose the fruit of Boragineous plants (such as Borage and Cynoglossum or Hound's-tongue), as well as of all Labiatæ.

A *Caryopsis* is an achenium with a thin and membranous pericarp, which adheres to the covering of the seed so closely, that the two are inseparable and undistinguishable. Such are the grains of Wheat and Indian Corn.

An *Utricle* is an achenium with a very thin and membranous pericarp, which does not adhere to the seed, as in Chenopodium or Goose-foot.

A *Drupe* or *stone-fruit* is a simple one-seeded and indehiscent fruit, with a thickened pericarp, which is separable into a hard and dry endocarp, and a pulpy or

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* There can be little doubt that the apparently simple fruit of Compositæ consists of two confluent ovaries with parietal placentæ, only one of which bears a seed. It is not therefore strictly correct to call it an achenium. This structure, which is externally indicated by the divided style, was pointed out by Robert Brown, in an Essay on Compositæ, published in the twelfth volume of the *Transactions of the Linnæan Society*, 1818.

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34. **Synconus**: a fleshy rachis, having the form of a flattened disk or of a hollow receptacle, with distinct flowers and dry pericarps.

Example. The Fig.

35. **Strobilus**: an ament, the carpels of which are ~~scale-like,~~ and spread open, bearing naked seeds; sometimes the scales are thin and separate, but they are often woody, and coherent into a single tuberculated mass.

Examples. Pinus, Cupressus, Juniperus.

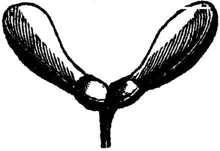
36. **Sorosis**: a spike or raceme converted into a fleshy fruit by the cohesion of the ovaries and floral envelopes into a single mass.

Examples. Mulberry, and the Bread-fruit.

juicy sarcocarp. The peach and cherry are familiar examples.

A *Nut* is an achenium in every thing, except that it results from the ripening of a compound ovary in which all the cells and seeds save one have disappeared during its growth (*Ex.* the chestnut, the acorn, *fig.* 61, *d*, &c.).

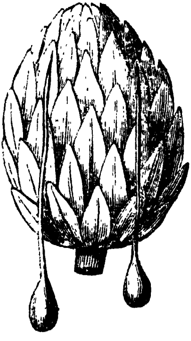
Fig. 102.



A *Samara* (*fig.* 102.) is an achenium or a nut, with a large wing at its summit or margin; as in the fruit of the Elm, the Ash, and the Maple. The fruit of the Maple consists of two samaras standing side by side and partially joined together.

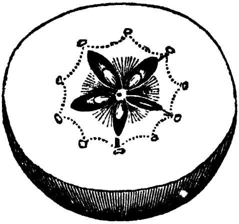
164 AGGREGATE FRUITS consist of several simple fruits clustered together upon the same receptacle, but not truly united or syncarpous. The cone of the Magnolia (*fig.* 103.), is an aggregate fruit, being composed of a great number of few-seeded carpels, compactly arranged upon an elongated receptacle, and opening by their dorsal suture.

Fig. 103.



The head of carpels in Ranunculus also forms an aggregate fruit; and those of the Raspberry and the Blackberry are of the same nature, except that the achenia become juicy in ripening: they might even be considered minute drupes. In the Strawberry, the large receptacle retaining all the nourishment of the fruit, becomes soft and juicy, while the minute achenia scattered over its surface continue hard and juiceless. The fruit of the Rose, as we have already had occasion to remark (142), consists of numerous bony achenia, attached to the walls of an urn-shaped cup, which is a hollow receptacle, invested with the fleshy calyx-tube (*fig.* 81, *a*, *c*.)

Fig. 104.



A *Pome* (*fig.* 104), such as the apple and pear, consists of several cartilaginous carpels, imbedded in a pulpy expansion of the receptacle (similar to that of the Strawberry, except in wholly surrounding the carpels); the whole being enclosed within a fleshy calyx, which makes a large portion of the bulk of the fruit. The junction of the calyx with the fruit proper is marked by a faint line; and the two portions may also frequently be distinguished by their taste, that which pertains to the receptacle having the finest flavor.*

165. COMPOUND FRUITS are those which result from the ripening of united or syncarpous ovaries. In strict accuracy we should have referred to this division the fruit of Boragineous and Umbelliferous plants, &c.; for these are truly compound fruits, formed by the union of two or more achenia. It seemed, however, more convenient to notice them in connection with the achenium.

The *Capsule* (*fig.* 91, 93, 94, &c.) is a general term for all compound fruits that are juiceless and somewhat membranous, opening by sutures. The name is also applied, with some qualifying term, to other forms not exactly agreeing with our definition. Thus, a dry compound fruit not opening by sutures, is called an *indehiscent* capsule; or, if it be somewhat pulpy or juicy as well as indehiscent, it is termed a *berry-like* capsule. A *pyxidium* (*fig.* 98) is a capsule opening transversely. A *pod-shaped* capsule, like that of Sanguinaria and Corydalis being composed of two carpels only, splits when ripe into two pieces, like a legume, from which it is at once distinguished by bearing seeds along both sutures. A *Silique* (*fig.* 105), the peculiar fruit of Cruciferous plants, is a pod-shaped capsule, rendered two-celled by a false partition which proceeds from the placentæ, consisting of the epicarp of each edge of the valves, meeting in the centre of the fruit. The silique has a septifragal dehiscence, the valves separating from the partition.

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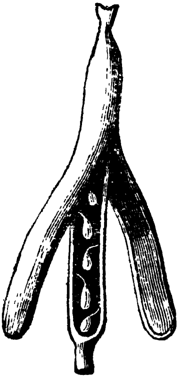
* The carpels of a pome are commonly considered as drupes, of which the cartilaginous portions are the endocarp only; the inner pulp being the confluent sarcocarp of the whole; but the view here given is more simple, and, on the whole, best sustained by all analogy.

Fig. 105.



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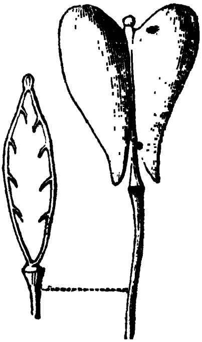

A silique proper, is always long and narrow. A short and broad silique, is called a *Silicle* (*fig.* 106), as in Shepherd's-purse (*Capsella Bursa-pastoris*).

A *Berry* (bacca) is a fleshy compound fruit, when ripe becoming a mass of pulp in which the seeds are imbedded: the grape and the gooseberry are familiar examples.

An *Orange* (hesperidium) is a many-celled fruit, the cells of which are filled with pulp, and the shell separable into a distinct endocarp and sarcocarp.

A *Pepo** is an inferior fleshy fruit with a firm rind, and pulpy partitions and placentæ; such as the gourd, cucumber, and melon.

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* "A *Pepo* is a fleshy inferior fruit, either indehiscent or bursting irregularly, and consisting of about three carpels, each of which is divided into two cells by its placentiferous margin being so intro-

166. COLLECTIVE FRUITS arise from the union or approximation of the pistils, and sometimes of the floral coverings also, of several flowers. The *Strobile* or cone of the Fir tribe is an instance of this kind (*fig.* 107), each scale representing a single flower. These scales are not bracts, as was formerly thought, but open carpels, bearing one or more seeds attached to their inner surface (169). *Fig.* 108, *a*, represents a ripened strobile of Cupressus (Cypress), and *b*, a magnified scale or open carpel from a young strobile of the same, showing the naked ovules.*

Fig. 107.

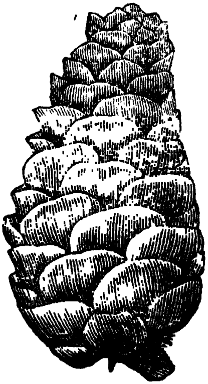
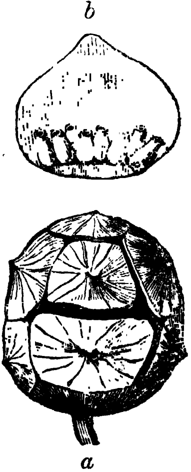


Fig. 108.



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flexed as to reach the dorsal suture. The sides of the carpels, and even sometimes the introflexed portion, usually become extremely thick and fleshy, forming the great mass of the ripe fruit, so that by losing the general character of dissepiments, they might almost be said to disappear; and thus at first sight a pepo would be said to be, and has been so described, a one-celled indehiscent fruit, with parietal placentas that send out sometimes false dissepiments towards the axis, as the cucumber and gourd.—Arnott, *Prodr. Fl. Ind. Orientalis*, *I.*, *p.* 340.

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* This figure is taken from Nees ab Esenbeck's *Icon. gen. plant.*

A *Sorosis*, like the Mulberry and Pine-Apple, is formed by the adhesion of many fruits of separate flowers, by means of their thickened and fleshy floral envelopes.

Sect. IX. *Of the Seed.*

167. The fruit consists of two parts,—the seed-vessel and the seed. The preceding section having been devoted to the consideration of the former, our attention is now to be directed to the latter organ.

A seed differs from a full-grown ovule, in containing an embryo, or organized body, capable of growing under favorable circumstances into a plant of the same kind as that which produced the seed. To a person familiarized with the structure of the ovule (144, 145), that of the seed presents little difficulty.

168. The arrangement of seeds in the pericarp is the same as that of ovules in the ovary; the terms used to express their situation, therefore, need not be repeated. They are attached to the placenta, by some point of their surface, either directly, or by the intervention of a funiculus or seed-stalk.

Seeds being always borne by the placenta, must of necessity be enclosed within a pericarp. Naked seeds, therefore, are anomalies which are only met with in the case of open ovaries. We had occasion to observe in another place (163), that the so-called naked seeds of Linnæus and all the earlier botanists, are one-seeded fruits. When this fact came to be established, it was too hastily inferred that true naked seeds have no existence in nature; a few instances excepted, in which they become so by the early rupturing of the seed-vessel, in consequence of their rapid enlargement. The Blue-berried Cohosh* (a common plant throughout the United States, flowering early in spring and ripening its seeds about midsummer,) presents a fine illustration of this kind. What are usually mistaken for berries, or rather drupes, in this plant, are seeds elevated on thick seed-stalks; at the base of which, shortly after flowering, the remains of the ruptured pericarp may be observed.

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* Leontice thalictroides, *Linn.* Caulophyllum, *Michaux.* The true nature of this drupe-like seed was pointed out by Robert Brown: see *Transactions of the Linnæan Society*, XII., p. 145.

169. There are, however, two families of plants, which exhibit truly naked seeds; in which neither the seeds nor the ovules are enclosed in a seed-vessel at any period of their existence, but are borne on the margins or base of flat and scale-like carpels. These families are the Coniferæ or Fir tribe, and the Cycadeæ, trees of tropical regions with the habit of Palms, agreeing with the Coniferæ in the structure of their woody tissue,* as well as in their flowers and fruit.

The cones, or strobiles of the Pine (*fig.* 107), and Cypress (*fig.* 108) are, therefore, heads of carpels. Each of these carpels is a single achlamydeous pistillate flower; the ovary not forming a closed sac, as in other plants, but remaining an open, leaf-like scale, bearing one or more seeds on some part of its upper surface. The carpels are also destitute of styles or stigmas, which would be useless organs in these simplest of all flowers; in which the pollen, being abundantly produced by the staminate flowers, falls directly upon the ovules, and impregnates them by immediate contact with their foramina. These curious facts were announced by Robert Brown† in 1825; and so surprising did they appear that some of the ablest living botanists hesitated to receive them, even on such authority. At the present day, I believe, the correctness of this view is unquestioned.

170. The seed-stalk, we have already remarked, is an appendage of the placenta, rather than of the seed, since when the seeds fall out of the pericarp, they leave the seed-stalk behind. The apex of the seed-stalk, however, sometimes expands about the base of the seed, in the form of a little cup; in

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* See note, on page 9.

† *Appendix to Capt. King's Voyage*, p. 22, et seq.

several instances wholly enclosing the seed, like an additional tegument. This body is called an *arillus* or *aril.* It is scarcely observable in the ovules, but attains its full size some time after their impregnation.

The aril in the genus Polygala usually appears as a hairy appendage* of the base of the seed (*fig.* 109, *a.*), of varied shape in different species. In Turnera cistoides (a rather pretty herb of the southern states, greatly resembling a Cistus), the seed-stalk expands into a scale, placed on one side of the seed (*fig.* 109, *b.*). The aril of Euonymus (of which several species are natives of the United States, known under the names of Spindle-tree or Burning-bush) is a spongy membrane, which wholly envelopes the ripe seed. The tough, fleshy and lacerated body which invests the seed of the Nutmeg, and is known in commerce under the name of Mace, is an aril. Of its office we are wholly ignorant.

In regard to the seed itself, to which we now return, we may consider firstly, its external appearance; and secondly, its internal structure.

171. The marking of the surface of seeds is greatly diversified in different species, often rendering the minuter kinds quite beautiful objects, when seen by the aid of a microscope. Frequently, indeed, their surface is nearly smooth and even, but it is often marked with rows of fine dots or points (*fig.* 109, *c.*), as in the Pink tribe. The seeds of the Hypericum family are commonly marked with longitudinal bands or bars, (*fig.* 109, *e.*); and in the Prickly-poppy (*Argemone Mexicana*), these longitudinal bands are connected by transverse lines, so as to form a kind of lattice-work on the surface of the seed (*fig.* 109, *d.*).

The scar left by the separation of the seed from its funiculus, is termed the *hilum*, (*fig.* 109, *f. g. h.* 1.). It is conspicuous in the Pea tribe, often having a different color from the remainder of the surface of the seed.

Close by the side of the hilum in some seeds (*fig.* 109, *f.* & *h.* 2.), and at the opposite extremity in others

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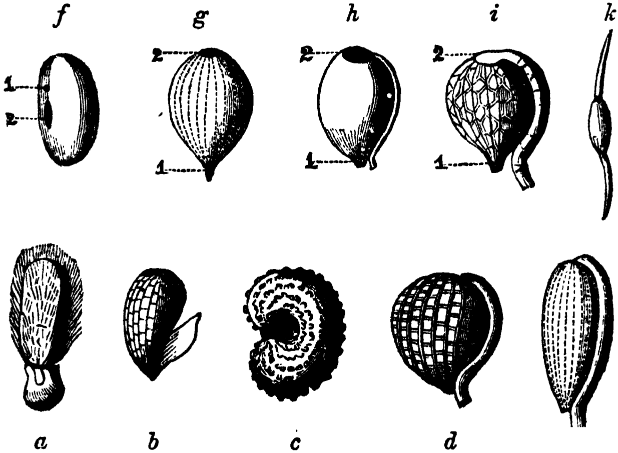
* This is not a *caruncle* or *strophiole*, as it has sometimes been called. A caruncle is a fungosity of the micropyle, as in Ricinus.

(*fig.* 109, *g.* 2.), a small hole, or at least a point, may be observed. This is the vestige of the foramen of the ovule (144), which is not wholly obliterated in most ripe seeds: it is now termed the *micropyle*, and indicates the apex of the seed, just as the foramen does that of the ovule. The dotted lines or bands marking the surface of the seed always converge to this point, so that by following them with the eye, the micropyle may be discovered, when by its minuteness it otherwise would escape detection. These lines all diverge from another point on the surface of the seed, which in *fig.* 109, *a*, *b*, *d*, *e*, *g*, *h*, *i*, is at the opposite extremity from the micropyle or apex. This spot is noticed in the ovule (*fig.* 82, 83, 84, *e.*) as the point where all its parts cohere with each other. It is called the *chalaza*; and in the seed as in the ovule, it indicates the true base of the organ.

Fig. 109.



Whenever the chalaza is visible apart from the hilum, as in *fig.* 109, *d*, *h*, *i*, *&c.*, (not confluent with it, as in *c*, *f*, *g*, of the same figure,) a prominent line or ridge runs along the inner face of the seed, connecting the chalaza with the hilum. This is the *raphe*, a slender prolongation of the seed-stalk, which is as conspicuous in the ripe seed as in the ovule. It is found in all seeds which have a chalaza distinct from the hilum, being quite conspicuous in the Sanguinaria or Blood-root (*fig.* 109, *i.*); in which it is white, and in the recent seed most strikingly resembling a little worm lying along the face of the seed.

It should here be remarked, that the terms employed to denote the three kinds of ovules, are likewise applicable to the seed; all seeds as well as ovules occurring under one of three forms, viz.: the *orthotropous* or straight, the *campulitropous* or curved, and the *anatropous* or inverted.

It rarely happens that a mere inspection of the surface will not suffice for determining to which of these forms any seed belongs; and thus the most essential points of structure may be ascertained with the greatest ease without the trouble of dissection, which requires considerable skill. Thus, in *fig*, 109, *g.* representing the seed of a plant of the Cistus or Rock-rose tribe, the lines which variegate the surface converge to a point at the end most remote from the hilum. At this point a dot or minute hole is observable; and, no raphe being present, we infer this to be the micropyle, and that the chalaza or base of the seed coincides with the hilum. The seed is therefore orthotropous; and this fact being satisfactorily settled, we also confidently infer that the embryo or rudimentary plant contained within (174) is straight, and also, that its radicle (174) points to the (apparent as well as real) apex of the seed.

The dotted lines which mark the surface of seeds of the Pink tribe (*fig.* 109, *c.*), converge to two points in the immediate vicinity of each other; one of these (with which the hilum is confluent, no raphe being present,) is the chalaza; the other is the micropyle or apex. We have learned; therefore, that the seed is campulitropous or curved; and furthermore, that the embryo is curved with it, presenting its radicle to the micropyle as in the former example; but, unlike that case, the micropyle is here contiguous to the chalaza and hilum. In *fig*. 109, *d*, *e*, *h*, *i*, and in by far the greatest number of seeds, a raphe and chalaza are present; and these marks positively characterize the seeds to be anatropous or inverted. What was said of the nature of anatropous ovules (145) sufficiently explains the apparent anomaly in the structure of these seeds, viz: that the hilum and chalaza are remote from each other, the latter occupying the apparent apex of the seed. In such instances we may expect to find a straight embryo, and the radicle, although pointing to the micropyle as in other cases, is here approximated to the hilum.

The surface in many seeds is bald, and in others is hairy, downy, woolly, bristly, &c.; but we cannot here attempt to notice all these diversities. The seed of Cotton is densely covered with long wool. A similar, but more silky wool covers one extremity only of the seeds of Epilobium or Willow-herb, and of Asclepias. It has been proposed to employ the silk of Asclepias as a substitute for cotton; but the fibres of the former want the property of adhering to each other, and therefore cannot be woven.

These tufts of hair or wool are called a *coma*. The coma has been confounded with the pappus (113), like that of the Thistle; but the latter belongs to the calyx. The hairs of both have the property of spreading by dryness and converging by moisture; as a consequence of which both subserve to the same end, viz: the lifting out of the seeds or fruits from the seed-vessel or receptacle, in dry weather, and their dispersion by the wind. The outer skin of some seeds extends on each side and forms a wing. The Bignonia and Catalpa furnish good illustrations of winged seeds. Narthecium has the outer membrane of the seed prolonged at each end into a thread-like appendage (*fig*. 109, *k*.), of the same nature as a wing.

172. A seed consists of the nucleus or kernel, and its integuments. The latter are collectively termed

the *episperm*,* or skin of the seed. It is usually composed of the two membranes (the primine and secundine) of the ovule. In some cases both membranes may be distinctly traced in the seed; in others, one of the coats disappears, probably by intimate adhesion to the face of the other. When both are present, the outermost is called the *testa* and the inner the *tegmen*.

The kernel consists of the embryo (174), and of the albumen (173) when the latter is present.

173. The *Albumen*† (*fig.* 110, 112) is the body which, in many seeds, is interposed between the embryo and the integuments. It arises from the deposition of a granular matter around the embryo, in the pulpy substance of the nucleus. Sometimes it is inconspicuous and small in quantity; in other cases it is much larger than the embryo, making up the principal bulk of the seed; as in the Cocoa-nut, Maize, and Wheat, (*fig.* 112,). The nature of albumen is also worthy of notice. It is *farinaceous* or *mealy* in Buckwheat, and in all Grasses, especially the Ceraliæ, whose seeds are employed for food. Mealy albumen is always innocent and nutritious, even in the most poisonous tribes. It has the texture of horn in Coffee, and in Cohosh (*Leontice*); and is oily in the Poppy tribe. In the Papaw (*Asimina*) and Nutmeg, it is *ruminated* or wrinkled, being pierced with irregular holes, caused by the presence of portions of the nucleus in which no glanular matter has been deposited.

The albumen was so named from its analogy in situation (and perhaps in office) with the albumen or white of the egg, which surrounds the embryo bird, as the former does the embryo plant. It forms a magazine for the nourishment of the embryo during its earliest growth. It is not an essential organ, the seeds of the Pea tribe, of Cruciferous plants, and of several other families, being wholly destitute of albumen; in which cases, the starch or other nourishing matter is deposited in the embryo itself.

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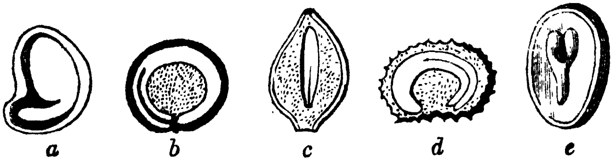
* Or by De Candolle, the *spermoderm*.

† *Perisperm* of Jussieu, and *endosperm* of Richard.

In several instances the embryo is enclosed within a little bag or sac,* which intervenes between it and the albumen when the latter is present, as in the seeds of the Water-lily. This sac is found in the Pepper tribe, the Ginger tribe (*Scitamineæ*), and in several others. It is one of the proper coats of the nucleus, which has not been absorbed, or converted into albumen, during the growth of the seed.

174. The *Embryo*, (*fig.* 110 and 111,) or rudiment of the new plant, is the most important organ of the seed; for the perfection, protection, and future support of which, all the other parts of the seed are destined. Of its real origin we have no positive knowledge. It makes its first appearance as a minute point or speck in the midst of the pulp of the nucleus, near the foramen of the ovule. It gradually increases until it occupies nearly the whole nucleus, and assumes the appearance of an organized body. When there is no albumen, the embryo fills the coats of the seed, as in the Pea and all Leguminous plants (*fig.* 110, *a.*): when the albumen is present, the embryo lies in its midst, or sometimes at one of its extremities. *Fig.* 110 represents the embryo of several seeds as brought into view by a longitudinal section.

Fig. 110.



The embryo becomes a plant by the mere development of its parts; and consequently it has in itself, in an undeveloped state, all the essential organs of vegetation, viz: a root, stem, and leaves. These several organs may usually be detected in the embryo as it exists in the seed. In its most common form, the embryo consists of a little stem with a single node, furnished with the rudiments of a pair of leaves (*fig.* 111). The little stem, or axis, has the power of growing from each extremity: the part which elongates in a downward direction forming the root, is called the radicle; and the opposite extremity, which by its upward elongation forms the stem, is termed the *plumule.* The two appendages of the axis, standing upon the neck or collet (22), are the *cotyledons.* They represent the first or lowest pair of leaves.

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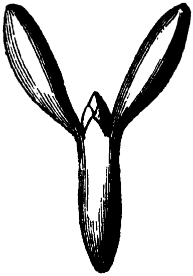
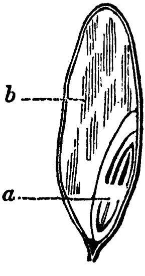
* This is called by Brown the *vitellus*, and by Lindley the *sac of the embryo.*

Fig. 111.



175. Thus far our illustrations of the embryo are taken from that form of the organ, which being the most perfect in its structure, and of the most frequent occurrence, may be assumed as the regular form or type, viz: that furnished with two opposite cotyledons or seed-leaves, and accordingly termed a *dicotyledonous* embryo. The embryo of the Grasses, (*fig.* 112), of the Palms, the Arum tribe (*fig.* 113), &c., is constructed upon the same plan, except that only a single cotyledon exists; or if two are present, they are not opposite to, but alternate with each other. These are examples of the *monocotyledonous* embryo. All the modifications of the organ are reducible to these two kinds. The number of the cotyledons, in itself considered, is a character of no very high rank; but it assumes special importance in consequence of its remarkably uniform coincidence with other peculiarities of structure. Thus, it is found that all Exogenous plants (33) have dicotyledonous embryos; and all Endogenous plants, monocotyledonous embryos. The embryo, therefore, affords additional characters for distinguishing the two leading divisions of Flower-

Fig. 112.



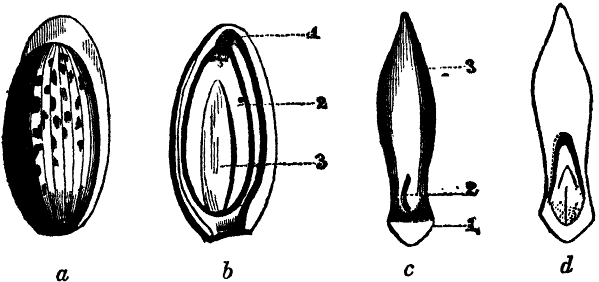
ing plants; characters even more constant than those which are drawn from the structure of the stem, leaves, and flowers. Thus, whenever we meet with a plant whose stem presents the Exogenous mode of growth, we shall also find, if the examination be prosecuted to this point, that its seeds contain a dicotyledonous embryo; the Endogenous growth of the stem as uniformly corresponding with the monocotyledonous embryo. So, therefore, from the examination of the seed alone, the general structure of the future plant may be predicted with great certainty.

Jussieu, the great founder of the natural system of botany, established the names of the two grand divisions of Flowering plants, upon the number of the cotyledons. These names are still in common use, although guarding against the unnecessary multiplication of terms, we have thus far avoided their employment. It may now be stated, however, that DICOTYLEDONOUS PLANTS and EXOGENOUS PLANTS, are different names applied to the same great division of Flowering plants; and that MONOCOTYLEDONOUS PLANTS and ENDOGENOUS PLANTS are also correlative. The number and disposition of the cotyledons is not an ultimate fact, but rather a consequence of the general law governing the position of leaves in Flowering plants. It was stated in its proper place (61), that the habit of Exogenous plants is to have opposite leaves; consequently, the embryo (which is a stem with a single node,) is necessarily provided with a single pair of leaves, or in other words, with two opposite cotyledons. For the same reason, Endogenous plants, whose habit it is to bear alternate leaves, have embryos with a single cotyledon or seed-leaf. The apparent exceptions to this rule do not really invalidate it. Thus, the Pines and Firs, which have more than two cotyledons, may be supposed to have two or more nodes, confluent by the non-development of the corresponding internodes. In this view, the anomaly is owing to the same cause as that which gives rise to whorled leaves in other cases. In some dicotyledonous embryos, the two cotyledons cohere by their edges, so as apparently to form a single one, as is observed in the Horse-chestnut. When the seed germinates the union is broken up, and the anomaly disappears.

The Dodder has a slender spiral embryo, which is destitute of cotyledons; a circumstance exciting little surprise, when taken in conjunction with the fact, that the full-grown plant is also leafless.

The embryo of monocotyledonous plants does not usually exhibit such a plain distinction into radicle, plumule, and cotyledons, as do the preceding examples. It is commonly a club-shaped body (*fig*. 113, *c*.), wholly entire, or with a little slit on one side near the base.

Fig. 113.



The blunt extremity is the radicle; the upper part is a cotyledon rolled up, or folded lengthwise, with its edges soldered together, except a little portion just at the base, where a minute slit appears.* From this slit the plumule emerges when the seed germinates.

In a few instances, the embryo of Endogenous plants exhibits a second cotyledon; the two being alternate with respect to each other. Not the number alone, but the relative situation of the cotyledons must also be taken into account. Thus Dicotyledonous plants may have more than two cotyledons, as in the Pines, but they are never alternate; and Monocotyledonous plants may have more than one cotyledon, but in such cases they are never opposite each other.

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* See *fig*. 113, *c*. representing the embryo of Calla palustris: 1, the radicle; 3, the cotyledon; 2, the slit from which the plumule emerges in germination. *Fig*. 113, *d*, is a section of the same.

176. As to its form, the embryo is either straight or curved. Orthotropous (*fig.* 110, *c.*) and anatropous seeds (*fig.* 110, *e.*) have straight embryos: in campulitropous seeds (*fig.* 110, *a*, *b*, *d.*) the embryo is curved. Its usual position in regard to the albumen, when the latter is present, is in the centre or axis, with the radicle at one extremity. Sometimes, however, instead of being enclosed in the albumen, the embryo is placed upon some point of its surface, as in Indian Corn, Wheat, and all Grasses, (*fig.* 112.). In the Amaranth tribe, it is curved like a ring around the outside of the albumen* (*fig.* 110, *b.*).

The situation of the embryo with regard to the chalaza and micropyle, is of great consequence in practical botany; and the law which governs its position in these respects has been already anticipated, viz: that, whatever may be the form of the seed, the radicle always points to the micropyle or true apex, and the summit of the cotyledons to the chalaza, or some point in its vicinity. Thus, the radicle in orthotropous seeds points from the hilum (*fig.* 110, *c.*), which is, in this instance, the true, as well as the apparent base of the seed; whereas in an anatropous seed, the radicle, retaining its position with regard to the micropyle, is approximated to the hilum (*fig.* 110, *e*); a consequence owing, as we have several times stated, to the inversion of the whole seed. A campulitropous or curved seed (*fig.* 110, *a*, *b*, *d.*), likewise has the radicle brought near the hilum, but from a different cause, viz: the doubling of the seed upon itself, without any displacement of the base.

177. The cotyledons are generally straight, and applied to each other face to face; but sometimes they are variously folded upon one another, or upon the radicle. This is particularly observable in the Cruciferæ,

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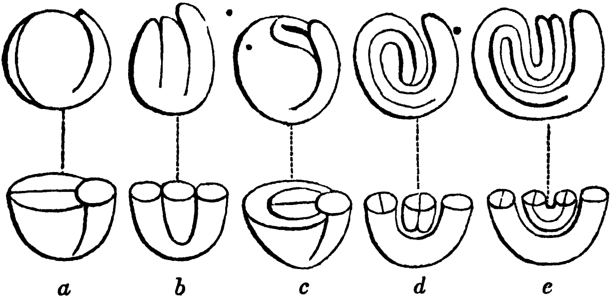
the embryo is surrounded with albumen, it is said to be When placed out of the axis of the latter, it is *eccentric.* is applied to the surface of the albumen, it is said to be and when rolled around it, *peripheric.*

in which the position of these several parts indicates the principal sections of the tribe. When the radicle lies along one of the edges of the cotyledons, as in *fig*. 114, *a*, the latter are said to be *accumbent*. When the back of one of the cotyledons is applied to the radicle, they are said to be *incumbent* (*fig*. 114, *b*.). Sometimes incumbent cotyledons are folded lengthwise upon each other, and round the radicle, as in *fig*, 114, *c*.; in several cases they are spirally incumbent (*fig*. 114, *d*.); and lastly, incumbent cotyledons are occasionally folded back upon themselves, as in *fig*. 114, *e*. The lower row of figures in the subjoined illustrations, represents the appearance presented in each case by a transverse section of the seed.

Fig. 114.



178. The seeds, if we may so call them, of Flowerless plants (Chap. V.) having no embryo, are of course destitute of cotyledons; hence they were named by Jussieu Acotyledonous plants; an ambiguous term, which is now seldom employed.

179. Two points remain to be considered respecting seeds, viz: their dispersion or separation from the parent plant, and their germination or development into a similar plant. The means by which the dispersion of seeds is effected, presents a subject of interesting consideration; upon which, however, the limits and design of the present work preclude us from entering. Their dissemination is regulated rather by the structure of the

pericarp, than of the seed itself. Fleshy or pulpy fruits, soon after ripening, separate from the stem by an articulation, as in the case of leaves; they fall to the ground in the neighbourhood of the parent plant, and the germinating seeds derive their early nourishment from the decaying flesh or pulp in which they are imbedded. The pseudospermic, or seed-like fruits (naked seeds of old authors) are frequently furnished with some special means to aid in their dispersion. For this purpose, the fruits of the Elm and Maple are provided with a membranous wing (*fig.* 192); and those of the Compositæ with a tuft of hairs or scales, in place of the ordinary limb of the calyx (*fig.* 71, *e*, *f*,); being by means of this apparatus scattered by the winds often to a great distance from the parent plant. Fruits furnished with a pappus are always crowded in dense heads, and surrounded by an involucre; the bristles of the pappus, being eminently hygroscopic, spread in dry weather, mechanically lifting the little fruits from the receptacle, that they may be submitted to the free action of the wind, by which they are widely dispersed. The seeds of the Willow and Poplar, &c, are provided with a *coma*, or tuft of hairs, which in a similar manner aids in their extrication from the seed-vessel, and dispersion by the wind. A shower, or even a humid atmosphere, causes the tuft to collapse, and the seed falls to the ground, and is imbedded in the moist soil under the most favourable circumstances for ensuring its future growth.

Capsular fruits usually open in dry weather, the most favourable period for the dispersion of the seeds: some capsules burst elastically with considerable force, projecting the seeds to a moderate distance. The Balsam is a familiar instance of this kind. In Hura crepitans, a West Indian and South American Euphorbiaceous plant, the bony pericarp bursts with a loud crack when ripe, and with such force as to tear in pieces several folds of strong cartridge paper in which the fruits are wrapped.

When seeds are protected from the joint action of those agents which facilitate germination, they may be preserved for any length of time, but under such circumstances they at length lose the power of germination. This is owing to a slow alteration of their texture under the influence of light, by which carbonic acid is decomposed, and carbon fixed in their tissue, all the parts of the seed becoming hardened; and in this condition vegetation cannot proceed. The period during which seeds preserve their vitality varies much in different species, and even in the same seeds under different circumstances. The exposure of a few weeks is sufficient to destroy the life of many seeds, especially those which have very thin and delicate integuments. On the other hand, nearly all seeds of the Pea tribe may be kept for several years without material detriment to their germinating power. Seeds of the Sensitive plant have been made to grow after an interval of 60 years, wheat after the lapse of 100 years*; and peas taken from the herbarium of Tournefort, where they had remained above 100 years, were made to germinate.

Seeds buried deep in the soil, being removed from the influence of air and light, and subjected to the uniform temperature of the earth, often preserve their vitality for many years, and are ready to grow when brought near the surface. Thus, when a waste field is cultivated, plants often spring up which have not been known to grow in that situation since the memory of man; and species for many years lost to florists, occasionally spring up on the site of old botanic gardens.

Only a small portion of the seeds produced by a plant grow, even exclusive of those which are devoured by animals. The great fertility of many plants, however, amply compensates for this loss. A single seed of the Thistle, it is said, will produce 24,000 seeds at the first crop, and consequently 576,000,000 on the second season. Some person had the patience to count the seeds produced by a single Poppy, and found them to exceed 30,000; and the fertility of many plants greatly exceeds this. By cultivation indeed, nearly all the seeds may be made to grow, but in a state of nature a large portion perish. Were it not so, there are thousands of species which would wholly cover the surface of the earth in a few years, wherever the climate permitted them to grow.

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* I place no faith in the statements I have somewhere seen, that grains of wheat taken from the hand of a mummy, where they must have remained at least 3000 years, germinated when placed under proper circumstances. In all the cases on record of the discovery of grain several hundred years old, the seeds have been found to be blackened, as if charred from the restoration of carbon by the gradual loss of oxygen and hydrogen.

180. Germination is the process by which the embryo contained in a seed begins to grow and develope the parts hitherto in a rudimentary state. The combined action of three external agents is indispensable to germination; viz: water, air, and a proper temperature. Water, slowly absorbed through the micropyle, or penetrating the integuments, softens all the parts of the seed, and also dissolves the matters stored up in the cotyledons or albumen for the nourishment of the growing embryo. The temperature most favourable to germination varies widely in different species; seeds being known to germinate at almost every temperature between the freezing and the boiling point of water. Nearly all plants, however, indigenous in temperate climates require a temperature of from 50° to 80° Fahr. for the germination of their seeds; the precise temperature in each case varying with the peculiar constitution of the species: a circumstance which explains the regular succession in the appearance of annual herbaceous plants, during spring and summer.

The access of the atmosphere is necessary to every period of vegetable growth; during the process of germination it is essential for the production of certain chemical changes soon to be noticed; viz. the formation of carbonic acid gas, by the union of the oxygen of the air with a portion of the carbon of the seed.

Light, which operates so beneficially in all other stages of vegetable growth, exerts an unfavourable influence upon the process of germination. The reason of this is evident when we remember that light promotes the decomposition of carbonic acid, and the fixation of the carbon in the tissue of plants (76), a hardening process, exactly the reverse of what takes place in germination. It is often stated that seeds will not germinate except in darkness, but this is untrue, as many examples prove. A strong light, however, almost always checks the process of germination at any stage, by fixing so much carbon in the young stem and root as to prevent further elongation.

A remarkable chemical change takes place in the albumen of a germinating seed, viz: the conversion of the starch into sugar, and, simultaneous with this, the disengagement of a quantity of carbonic acid gas, and a slight elevation of temperature. It is these changes which are effected in the malting of barley. If seeds be made to germinate in a confined portion of atmospheric air, it is found that the bulk of the air is not at all affected by the process, but the quantity of oxygen gradually diminishes, and is replaced by an equal volume of carbonic acid. Inasmuch as when oxygen gas combines with carbon it suffers no change in volume, chemists conclude that the conversion of a portion of the oxygen of the air into carbonic acid, and of the starch and other nutritive principles stored in the seed into sugar (and finally into gum ?), results solely from the combination of the oxygen of the air with a portion of the carbon of the starch, &c.; the other elements remaining unaffected.

While these changes are in progress, the seed softens, the embryo absorbs the nutritive matter prepared for its use, swells, and bursts its envelopes; the radicle is protruded, and taking a downward direction (84), fixes itself in the soil, from which it now derives its support; the plumule also elongates, and rising upwards in the air, forms the stem of the young plant, in due time developing leaves for the elaboration of the crude nourishment absorbed by the root. The process of germination is now finished, the plant hereafter depending upon its roots and leaves for the accumulation and digestion of its proper nourishment. Soil is by no means essential for the germination of seeds, the requisite nourishment being deposited in the seed itself at the time of its formation, and the embryo requiring only the joint influence of air, moisture, and a proper temperature, to enable it to grow, and appropriate this nourishment. Yet a seed in spring or summer, lightly covered with soil, which, while it excludes the light, is freely penetrated by the air, moistened by showers, and warmed by the rays of the sun, is in the most favorable condition for germination.

The mode in which the embryo disengages itself from the integuments of the seed varies in different species; commonly they are ruptured by the swelling of the embryo, but sometimes (*Ex.* Commelina) both the radicle and plumule pass out through the micropyle. If the radicle is enclosed in a sheath (called a *coleorhiza* or root-sheath), as in most Endogenous plants (thence named by Richard *Endorhizæ*), this is soon perforated by the radicle in its descent as in *fig.* 116. In Exogens (*Exorhizæ* of Richard,) the radicle is naked, or destitute of a root-sheath. In most Exogenous plants, the cotyledons are elevated into the air by the ascending stem, (as in *fig.* 115,) and acquiring a green color, they perform all the functions of leaves until other leaves make their appearance, when they soon wither and perish. Their shape is usually different from the primordial (61), and all the succeeding leaves. In the Oak, Horse-chestnut, the Pea, and several other Exogenous plants, the plumule alone elongates into the air, the cotyledons remaining under ground, and finally decaying.

Fig. 115.

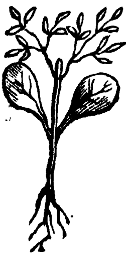
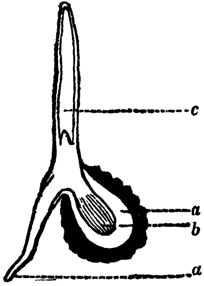


Fig. 116.



In Endogens, the single cotyledon does not rise out of the ground, but remains within the integuments of the seed during germination; as is seen in *fig.* 116, which represents the transverse section of a germinating seed of a species of Scirpus.*

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* *Fig.* 116. *a*, the albumen ; *b*, the cotyledon ; *c*, the plumule ; *d*, the radicle, which has burst though the coleorhiza.

Sometimes seeds begin to germinate while yet attached to the parent plant, or enclosed in the seed-vessel; this not uncommonly happens in seeds surrounded with pulp, as in the Cucumber, Melon, &c. In a few plants the seeds not only germinate, but even take root in the soil before they separate from the parent plant. The most remarkable instance of this kind is seen in the Mangrove, a tree which forms dense thickets along the very borders of the sea in tropical regions. In this plant germination takes place while the seed is yet contained in the pericarp: the radicle pierces the seed-vessel, and elongates until it reaches the soft mud in which such trees grow, where it strikes root, and afterwards separates from the parent plant. Such plants are said to be *viviparous.*[*]

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[*] This term is often very improperly applied to those plants, in which the flower-buds revert more or less completely to leaf-buds; whereas such plants, instead of really becoming viviparous, rarely perfect their seeds. Of this kind are several alpine species of Poa and other Grasses, and the so-called viviparous varieties of the Onion. In several Cyperacous plants, all the scales (*bracts*) of a spikelet are not unfrequently transformed to leaves, and the flowers in their axils disappearing, the spikelet thus reverts to a branch, and presents a somewhat similar appearance to the species of Poa above-mentioned. No more direct proof than this can be desired respecting the nature of a spikelet. Cyperus dentatus, *Torr.* often presents this appearance in a beautiful manner. This retrograde metamorphosis of the floral organs is frequently exhibited in the species of Juncus, where it is induced by the bites of insects, the flower being changed into a compact bunch of scale-like leaves. One species, J. dichotomus, *Elliott.* (J. *viviparus* of Conrad) is almost always found in this state. Although totally different from the viviparous state, these instances are very instructive, both as showing the true nature of floral organs, and also as exhibiting the analogy of seeds with leaf-buds.

CHAPTER

OF FLOWERLESS PLANTS.

181. Hitherto our attention has been exclusively directed to the consideration of Flowering plants; in the present chapter we shall briefly notice the second grand division of the Vegetable kingdom, viz: that of Cryptogamous or FLOWERLESS PLANTS. Flowering plants justly claim the greatest share of our attention, not only on account of the greater complexity of their structure and the variety of their organs, but also because they contribute more directly to the supply of our wants, and the gratification of our senses. The organization of Flowerless plants is far more simple than that of those to which our investigations have, thus far, been confined. The almost infinite variety of their external forms, however, compensates for the greater simplicity of their internal structure.

No person, whose mind is in an ordinary degree susceptible of intellectual pleasure, can attain even to a superficial acquaintance with the structure and economy of Flowerless plants, without appreciating the enthusiasm their study so generally inspires in those botanists whose attention is especially directed to these investigations;—an enthusiasm which is usually in an inverse ratio with the apparent significance of the object.

In an early part of this work (p. 16.), we gave the leading characteristics of the two great classes, into which the vegetable kingdom is so naturally divided. With Linnæus we may apply to these grand divisions the names of *Phænogamous* and *Cryptogamous* plants; signifying that the former are manifestly furnished with fertilizing and seed-bearing organs; and that in the latter these organs are concealed from view. These names are still in common use, and would be quite appropriate were it not that the term

Cryptogamia assumes the fact that these plants are truly furnished with stamens and pistils, and consequently bear seeds. To avoid this assumption, some authors have substituted for the name Cryptogamous, that of *Agamous* plants.

Jussieu, who supposed with Linnæus that all plants are reproduced by seeds, was the first to observe that those of all Flowering plants are furnished with cotyledons or seed-leaves, which are uniformly wanting in Flowerless plants: hence, he called the former *Cotyledonous*, and the latter *Acotyledonous* plants. Richard* went a step further, and observing that what are called the seeds of Ferns, Mosses, &c., have no embryo and no single growing point, but vegetate indiscriminately from any part of their surface, he proposed to substitute the names *Embryonatæ*, or plants whose seeds have an embryo, and *Exembryonatæ*, or plants whose seeds are destitute of embryo, for the Linnæan terms Phænogamous (or Phanerogamous) and Cryptogamous plants. But the so-called seeds in the latter class being destitute of embryo, are not seeds in the proper acceptation of the term, and in their structure and origin offer few points of resemblance with the seeds of Flowering plants. To avoid, therefore, the ambiguity of including two different bodies under the same name, botanists apply the term *spores* or *sporules* to the substances produced by Cryptogamous plants in the place of seeds.

We have seen that the office of the flower is to produce and to perfect seeds, and hence may infer that Cryptogamous plants are incapable of bearing flowers, which their economy does not require; and in examining the reproductive organs of such plants, we do not observe, in any of their diversified forms, either stamens and pistils, or calyx and corolla, or any organs which, in accordance with the laws regulating the structure of a flower, can be considered as modifications of them. A lively fancy, indeed, acting under the erroneous impression which the simple and elegant theory of Linnæus has so long perpetuated, viz: that *all* plants are furnished with stamens and pistils, has in some cases discovered organs to which these names might be applied with some show of plausibility; but in most instances these analogies are far-fetched and highly unsatisfactory. We distinguish these two classes, therefore, by the names of Flowering and Flowerless plants in preference to all others, because these terms are simple expressions of our actual knowledge, apart from all theoretical considerations, and are founded upon the presence or absence of conspicuous and well-known organs.

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* *Analyse du Fruit*, par Louis-Claude Richard. See also Lindley's translation, London, 1819.

The difference between Flowering and Flowerless plants is not solely confined to their reproductive organs. The organs of vegetation in the former are clearly distinguishable into root, stem, and leaves; in the latter these organs are sometimes partially, and often wholly confounded. The stems of Flowering plants are capable of increasing in diameter, by means of fibrous and vascular tissue, in one of two modes, distinguished by the names of Exogenous or Endogenous growth (33). On the other hand, Flowerless plants, even those having distinct stems, are destitute of any special provision for increase in diameter. We are aware that cellular, vascular, and woody tissue all essentially enter into the composition of Flowering plants; and it is stated that the two latter are wanting in Flowerless plants. Hence the former class also bears the name of *Vascular*, and the latter of *Cellular* plants. It must be remembered, however, that these two distinctions do not entirely harmonize in the plants they embrace, and that only a portion of Flowerless plants are formed of cellular tissue solely. As in the animal kingdom, so also in the vegetable, Nature passes from the more complex to the simplest organization, not by an abrupt transition, but by a beautiful series of gradations. Thus, spiral vessels, the most perfect kind of Vascular tissue, are absent in all Flowerless plants, with the exception of Ferns, Lycopodiaceæ, &c., in which they exist very sparingly.

Ducts abound in the stems of Ferns, the Equisetaceæ or Scouring-rush tribe, the Lycopodiaceæ, &c.; but are wholly wanting in Mosses, Lichens, Fungi, &c. The Mosses also, and all the forms of Flowerless vegetation below them, exhibit no trace of woody fibre, but the whole fabric is truly and exclusively cellular.

Flowerless plants may accordingly be divided into two sub-classes, of nearly equal value with the Exogenæ and Endogenæ of the first class; viz:—

1st. The *Fibro-Vascular Flowerless plants;* which form the connecting link between Flowering and Flowerless plants, approaching the former by the presence of Vascular tissue and woody fibre, and in having distinct stem-like trunks, yet agreeing with the latter in being destitute of flowers, and in the production of sporules instead of seeds.

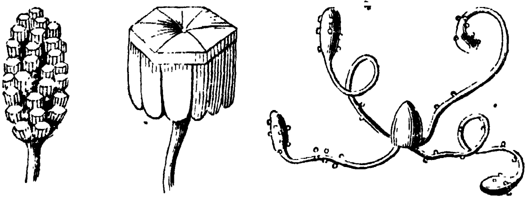
2nd. *Cellular Flowerless plants;* which are wholly composed of cellular tissue, and (with the exception of Mosses) exhibit no distinction of stem and foliage.

To the first division belong the Equisetaceæ, the Ferns, the Marsiliaceæ, and the Lycopodiaceæ: to the second, the Mosses, the Hepaticæ, the Characeæ, the Algæ, the Lichens, and the Fungi.

Each of these tribes is constituted, in regard to its reproductive organs especially, upon a plan so peculiar to itself, that an acquaintance with any one of them affords but little assistance in the study of the remaining families. General views, therefore, being here of little service, we proceed to give a very brief account of each tribe, confining ourselves almost wholly to a description of the more prominent organs.

I. EQUISETACEÆ. *Horsetail. Scouring-rush.*

Fig. 117.



182. We commence with this remarkable family, composed of the single genus Equisetum, which has little resemblance to any other tribe of plants whatever. Linnæus ranked these plants with the Ferns, from which their appearance is very dissimilar. Their hollow cylindrical stems are separable at the joints, by which the cavity of the stem is interrupted at regular distances. Each articulation is surrounded by a membranous, toothed sheath, which is a prolongation of the lower portion or internode; the teeth of the sheath usually corresponding in number with the furrows of the stem. They are all leafless, unless the sheath may be considered as a whorl of abortive leaves grown together. Some species have simple stems, others are branched, the branches being placed in whorls at the joints, and having the same structure as the stem itself. Each whorl usually consists of as many branches as there are teeth to the sheath. The Equisetums exhibit annular ducts, but no spiral vessels have been detected; the cuticle is furnished with breathing-pores. They are especially remarkable for the quantity of silex which is deposited and retained in their tissue. In one species, the well-known scouring-rush (*E. hyemale*), so much silex is accumulated beneath the cuticle, that the plant is commonly employed for polishing furniture and metallic household utensils. "On subjecting a portion of the cuticle of

this species to the analysis of polarised light, Dr. Brewster detected a beautiful arrangement of the siliceous particles which are distributed in two lines parallel to the axis of the stem, and extending over the whole surface. The greater number of the particles form simple straight lines, but the rest are grouped into oval forms, connected together like the jewels of a necklace, by a chain of particles forming a sort of curvilineal quadrangle; these rows of oval combinations being arranged in pairs. Many of those particles which form the straight lines, do not exceed the 500th part of an inch in diameter. Dr. Brewster also observed the remarkable fact, that each particle has a regular axis of double refraction. In the straw and chaff of Wheat, Barley, Oats, and Rye, he noticed analogous phenomena; but the particles were arranged in a different manner, and displayed figures of singular beauty. From these data he concludes that the crystalline portions of silex and other earths, which are found in vegetable tissues, are not foreign substances of accidental occurrence, but are integral parts of the plant itself, and probably perform some important office in the process of vegetable life."*

The stems of this tribe are terminated by an oblong or conical spike (*fig.* 117, *a.*), composed of several whorls of pedicellate, peltate, many-angled scales or disks (*fig.* 117, *b.*). From the under side of these scales a number of wedge-shaped involucres project downwards, and bursting longitudinally on the inside, discharge a multitude of little bodies, the nature of which is not very well understood. These bodies, seen under a microscope, consist of a central green knob, furnished at the base with four elongated club-shaped filaments (*fig.* 117, *c.*). When moist, these filaments are twisted spirally around the central body, but when dry they unroll and expand themselves elastically. The filaments have many exceedingly minute granules sticking to them, as is represented in the figure.

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* Greville, *Flora Edinensis*, p. 214.

Little is known of the nature of these organs. According to Hedwig, the central body is a *pistil*, the elastic filaments *stamens*, and the minute grains which adhere to them, *pollen*.

Ad. Brongniart considers the knob as a naked seed, and the four filaments as stamens, or rather masses of pollen, thus approximating the tribe to the Coniferæ; but the filaments can at most be only rudiments of stamens; and the central body has not the structure of a seed. Arnott* conjectures that the knob is a receptacle, analogous to that of some Ferns, and that the filaments supply the place of the theca and ring of these plants, while the minute granules are the sporules. The germination of these plants, as observed by Agardh† and Vaucher,‡ sufficiently disproves this view, for the green knob itself is seen to grow into a new plant. The office of the filaments is undoubtedly to assist mechanically in the dispersion of the sporules, and this contrivance is analogous to several equally curious, hereafter to be noticed in the remaining families of Flowerless plants.

The germination of the sporules in this tribe exhibits little analogy with that of true seeds. They in the first place increase considerably in size, and then project from some part of their surface a pellucid and extremely delicate tube or fibre, which becomes a rootlet; it next sends upwards a number of slender and articulated green fibres, so closely resembling some Confervæ, that Agardh, the most acute Algalogist of the age, at first mistook them for a plant of this kind. Gradually, these green fibres grow together into a single body, from which springs the stem with its lowermost sheath; the descending rootlets also joining together, produce a single root which descends vertically and buries itself deeply in the soil.

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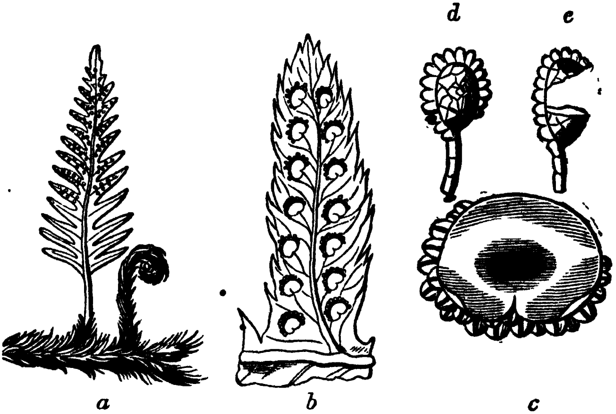
* *Art.* Botany, *in Enc. Brit.*, *p.* 54.

† *Mem. Mus. d'Hist., Nat. IX.*, *p.* 283.

‡ See same work, X., p. 429.

II. FILICES. *The Ferns.*

Fig. 118.



183. The Ferns, the most beautiful and generally admired of Flowerless plants, have always been especial favorites with botanists. They are also the largest and most conspicuous plants of this class; for, although the Ferns of the United States, and of all northern climates, have prostrate stems, and consequently do not rise at most above three or four feet in height; yet in tropical countries their trunks are often erect, and frequently attain the height of seventy or eighty feet. The Tree-Ferns of the Tropics are said to be objects of incomparable beauty; their straight, unbranched trunks often rising, like those of palms, as high as forty or fifty feet without a leaf.

The stems of Ferns, whether prostrate or erect, present neither the Endogenous nor the Exogenous structure, but seem to be formed of the united bases of the leaves cohering around a hollow or cellular axis. They continue to elongate from their anterior extremity, by the production of new leaves, but when once formed, they suffer no further increase in diameter. A transverse section exhibits neither layers nor bundles, but irregular and sinuous strata of wood, imbedded in a spongy matter.

The trunk is a *rhizoma* when it is prostrate and creeping upon or beneath the soil: when erect, like the trunk of a tree, it is termed a *caudex*. The rhizoma throws up leaves, or, as they are called in this tribe, *fronds* (*fig.* 118, *a.*), which, when young, are rolled up or circinate, like the Sundew and the Cycadeæ among Flowering plants, except that here they are rolled outwardly instead of inwardly. The great peculiarity of this family is, that their fructification is borne upon the back of the frond, which thus becomes both a peduncle and a leaf.

The stalk of the frond, or that portion which intervenes between the stem and the expanded or leafy part, like the petiole of a leaf, is called the *stipe* (*fig.* 118, *a.*). The portion which extends through the lamina from its base to its apex, like the midrib of an ordinary leaf, is termed the *rachis*. The frond is *simple* or *lobed*, *pinnatifid*, *pinnately* or *palmately divided*, *&c*, as in true leaves. The divisions, however, are never articulated upon the rachis, as in compound leaves.

The veins or branches of the rachis which ramify in the frond, are usually parallel and forked, but not confluent with each other so as to form a network (*fig.* 38.). To this, however, there are so many exceptions that it cannot be considered characteristic, as was formerly proposed. It is nevertheless so common, that the only well-marked deviation from it in the Ferns of the United States, occurs in Onoclea sensibilis, which exhibits beautifully reticulated veins.

In describing the fructification of Ferns, we take as the type of the family, that large division known by the name of *dorsiferous Ferns*, or *Polypodiaceæ*. On the back or under side of the frond of these Ferns, small, light-colored spots appear, either in the forks of the veins or at their extremities, or occasionally on the
vein. As these spots grow, they become
ct, and finally appear in the form of clusters
fig. 118, *a*, *b*.), called *sori*, or *fruit-dots*.

The little grains of which they consist are termed capsules, or more properly *thecæ ;* the former appellation being in strictness confined to a peculiar kind of seed-vessel. *Fig.* 118, *d.*, represents a theca as it appears under the microscope. It is a flattened bag of cellular membrane, fixed to the frond by a pedicel or stalk, which is sometimes very short. The stalk, which is composed of a row of thickened and strong cellules placed end to end, extends along one edge of the theca so as nearly to surround it as in a ring. This *ring* (*annulus*, *gyrus*), as it is called, does not in these cases pass entirely round the theca ; it is therefore said to be *incomplete*. When the theca is ripe, the ring becoming dry and being very hygrometric, has a disposition to straighten itself; and when this tendency acquires sufficient force, the theca gives way on the opposite side, and the ring straightens by a jerk, which tears the the thecæ asunder, scattering abroad the minute dust or *sporules* which it contains (*fig.* 118, *e.*). This beautiful contrivance may be observed in action in the newly-ripened fruit-dots of any dorsiferous Fern, under an ordinary lens, in a fine dry day.

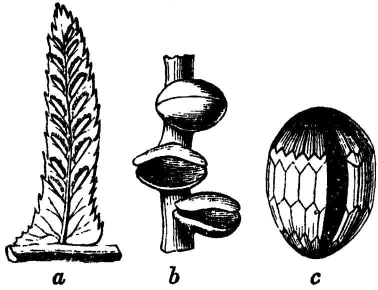
The thecæ are sometimes formed above the cuticle, as in Polypodium (*fig.* 118, *a.*): in this case the fruit-dots are said to be *naked*. More frequently the thecæ originate beneath the cuticle, and a portion of the latter, separated from the parenchyma, forms a membranous covering for the fruit-dot, called an *involucre*, or more properly an *indusium*. The indusium is sometimes fixed to the frond by its centre, opening all around the margin, when it is said to be *peltate*. (See *fig.* 118, *c*, which represents the fruit-dot of a species of Aspidium much magnified.) In the genus Aspidium it is always round and peltate, or reniform, or semicircular, attached by a point on one side and opening on the other, as if consisting of half a peltate indusium. The genus Asplenium bears elongated indusia, which are fixed to the veins of the frond by the whole length of their outer margin, and opening on the opposite side (*fig.* 119, *a.*). In Woodsia the indusium is placed beneath the fruit-dot. The Adiantum, or Maiden-hair, has oblong fruit-dots situated close to the margin of the frond, reflected portions of which form the indusium. In Pteris, the fruit-dots are confluent, forming unbroken marginal lines, and the indusium consists of the entire reflected margin of the fertile frond.

In Trichomanes and Hymenophyllum, which are distinguished from other Ferns by their extremely thin and delicate foliage, the vein to which the thecæ are attached, projects into the fruit-dot; being included in the cup-like extremities of the lobes of the frond, and it is then called a receptacle. Of this beautiful group of Ferns, none are natives of the United States; for although Hymenophyllum ciliatum has retained a place in our Flora since the time of Pursh, it has been found by no succeeding botanist, and should, doubtless, be excluded.

In some genera, the frond is so entirely covered with fruit-dots, that it loses its foliaceous appearance and resembles racemes or spikes; as in Onoclea and Struthiopteris, which differ from the ordinary dorsiferous Ferns only in their contracted fertile fronds.

There is a small group of Ferns in which the fruit-dots cover the whole under surface of the frond, altering its appearance as completely as in the cases last referred to; but they differ from these in having thecæ destitute of rings, the surface of which is longitudinally striate or wrinkled, instead of reticulated. These thecæ are always sessile, and usually open by a regular cleft from top to bottom (*fig*. 119, *c*.). Three genera of this group are found in the United States. One of these is Osmunda, to which three showy and widely diffused species belong. To this section also belong s the elegant and rare Lygodium palmatum, which

Fig. 119.



is remarkable for its twining habit; and the curious little Schizæa pusilla, which is still more rare, being only found in this country at a few localities in the Pine barrens of New Jersey.

We omit all notice of several groups of Ferns, which present interesting deviations from what we consider the primitive or typical form of the tribe, since none of them are natives of this country. We pass to a remaining section, comprising two genera, viz: Botrychium, some species of which are popularly called Rattlesnake-fern, and Ophioglossum or Adder's-tongue. These plants differ so greatly from true Ferns in several particulars, that some eminent botanists have wished to exclude them from the family. In the first place, they have no rhizoma, but an upright stem and fibrous roots; and their vernation is straight, instead of circinate as in all other Ferns. Their thecæ have neither rings or striæ, but are smooth and coriaceous, opening transversely by two valves, and aggregated on the frond in the form of simple two-rowed spikes in Ophioglossum; or presenting branched spikes in Botrychium. It should be added that the sporules of the latter are inflammable, like those of the Club-moss tribe. *Fig.* 119, *b*, represents several thecæ of a species of Botrychium.

Ferns may be raised from their sporules as readily as Flowering plants from their seeds. In germination "the sporule elongates into a club-shaped body, which by degrees expands into a flat, cellular and somewhat foliaceous substance, sending out radicular fibres from its margin. This body appears by elongation to become the rhizoma, for soon after it is fixed to the ground, it emits from a point on its upper surface a thread, which is afterwards the stipe and leafy part of the plant."

Stamens and pistils have been diligently sought after in this family. All the older botanists agreed in considering the thecæ as pistils; but we may infer how unsuccessful was the search for stamens, when Micheli and Hedwig thought they had discovered them in certain glandular hairs; Gleichen, in the breathing-pores; Hill, in the ring of the thecæ; and Kœlreuter in the indusium. At the present day, probably no one doubts that Ferns are truly flowerless.

Concerning the nature of the thecæ, an ingenious and highly probable theory was first proposed by Prof. Lindley, in his Outlines to the First Principles of Botany.* In this view a fruit-dot is considered to be a cluster of transformed fronds, or leaves; the stalk and ring representing the stipe and rachis, or in other words the petiole and midrib of a leaf; and the theca itself, the lamina with united margins. This theory is confirmed by those viviparous Ferns, which bear minute fronds in the place of fruit-dots.

III. LYCOPODIACEÆ. *The Club-Moss tribe.*

184. The plants comprehended in this tribe mostly belong to the genus Lycopodium, which was placed by Linnæus among the Ferns. They agree with the Ferns in having annular ducts and even spiral vessels, in the structure of their stems, and in being furnished with breathing-pores; but differ in their veinless leaves, and also in their fructification and habit. They are generally low or trailing evergreens, with branching stems, densely crowded with firm, usually narrow and sharp-pointed veinless leaves; and so much resemble Mosses, except in their larger size, that several species are popularly known by the name of Club-moss. Other species are called Ground-Pine; and indeed their habit and general appearance is best indicated by saying that they are intermediate between Pines and Mosses. No species are now known, that exceed the height of 2 or 3 feet, and commonly they are very much smaller than this; yet the examination of fossil stems seems to prove the former existence of large trees of this family.

Plants of this order are not very numerous in northern or temperate regions; our species grow in company with Mosses, in moist or dry ground, or on rocks, usually preferring the deep shade of forests.

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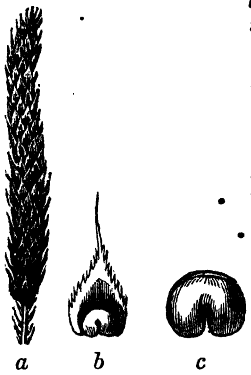
* See also Lindley's *Introduction to the Natural System of Botany.* Amer. Ed. p. 310.

Their fructification consists of thecæ borne in the axils of the leaves, but sometimes the latter are so much crowded and reduced in size, that the fructification apparently presents a spiked arrangement (*fig.* 120, *a.*). The thecæ (*fig.* 120, *b*, *c*,) are from one to three-celled, and one to three-valved. They contain either a light yellow powder in great abundance, composed of very minute grains, or of two or three much larger seed-like bodies. The latter are usually placed below the former when both are present in the same plant; they are undoubtedly sporules, since young plants have been raised from them. Some species bear the powdery substance only, the nature of which is not very well known. It has been thought to be pollen, yet several botanists affirm that plants will grow from it as from the larger sporules. This powder in all the species of Lycopodium is very inflammable, flashing like gunpowder, but without leaving any unpleasant odor; hence it is employed in the preparation of theatrical lightning.

Fig. 120.



IV. MARSILIACEÆ.

185. This is a little known tribe, consisting of a few inconspicuous aquatic plants, which generally escape observation rather from the situations in which they grow than on account of their rarity. Isoetes (which is sometimes referred to the preceding tribe) grows in the mud at the bottom of rivers and pools, and has the appearance of a little grass or rush. Marsilea and Pilularia have creeping stems or runners, with a few cylindrical, rush-like leaves, which are coiled in verna-

tion, like the Ferns. The fructification of Pilulari consists of globular involucres, not opening, divide internally into several cells which contain the thecæ these bodies are sessile in the axils of the leaves. Th of Marsilea is analogous to the former, but the inv lucre is stalked and dehiscent.

Salvinia and Azolla have the vegetation of Junge mannia (187), and are found in tufts floating on th surface of stagnant water, among Lemna or Duckweed, Riccia, &c. The structure of their organ especially those of fructification, is involved in obscurity. The tribe seems to be intermediate between th Ferns and Hepaticæ (187). Pilularia has spiral vessel each leaf, or rather petiole, being traversed along it axis by a few vessels of this kind, with fibres intermixed.*

V. Musci. *Mosses.*

186. We have now arrived at those forms of vegetation in which neither woody fibre nor vessels exist, bu all the organs are wholly composed of cellular tissue The Mosses are by far the most curious and complicated in their organization of all the tribes in this division having stems composed of elongated cellular tissue and furnished with leaves which, although entirely cellular, are arranged with as great regularity, and are as varied in their forms, as those of Flowering plants. The organs of fructification in this tribe exhibit greater diversity and more complicated structure than the Ferns.

Mosses rank among the smallest of plants; they seldom exceed the height of a few inches; and many are so minute that they would wholly escape our observation if they did not grow in patches. Several species, indeed, are scarcely visible to the naked eye; and yet they have a stem, leaves, fruit, and other organs, as completely formed as the largest plants of the family.

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* *De Pilularia dissert. Bot.*—*Jac. Georg. Agardh*, Lund. 1833. pp. 29

In general, Mosses, like Ferns, delight in shady and damp places; yet every variety of moisture and dryness, of shade or exposure, and almost every diversity of soil, is provided with its appropriate species. Several species are exclusively found on walls and roofs; a few grow on the southern sides of bare rocks, where no other vegetable could be sustained, drawing all their nourishment from the atmosphere, and by their decay furnishing a bed of vegetable mould, in which plants of higher organization take root. Some kinds are peculiar to the bark of trees, and others are partial to their prostrate and decaying trunks. Bogs and morasses abound with fine Mosses; in such situations we find Sphagni or Peat-Mosses in great abundance, and several other kinds, which in these situations grow very luxuriantly. The species of Fontinalis grow in running water, where they attain a greater length than any other Mosses; and the little rivulets which meander through fields and waste places are often entirely concealed by beautiful light-green patches of Bryum androgynum and Bartramia fontana. Some species are peculiar to granitic rocks, others to limestone; some grow exclusively in sand, and others are confined to clay. One Moss, *Funaria hygrometrica,* which grows in every part of the world, is sure to spring up wherever any thing has been burned upon the ground, and also in the neighborhood of charcoal-pits; whence its French name of *La Charbonière.* Most species of Splachnum, although found in almost every country, have the singularity of growing only upon decaying animal substances; one species, *S. angustatum,* which is exclusively met with in such situations, Dr. Hooker found growing vigorously upon an old stocking; it was seen upon the hat of an unfortunate traveller who had perished on Mount St. Bernard, and was also discovered by Capt. Parry in Melville Island, growing in the cavity of the nose on the skull of a Musk-ox.*

Mosses imbibe moisture with the greatest avidity. Those which are at all exposed to extremes of dryness in the hot season, wither and become crisped and apparently lifeless; but a slight shower, or the dew of a summer's evening, speedily restores them to their former freshness. Specimens which have been for a long time preserved in the herbarium, become, on immersion in water, as fresh as when just gathered.

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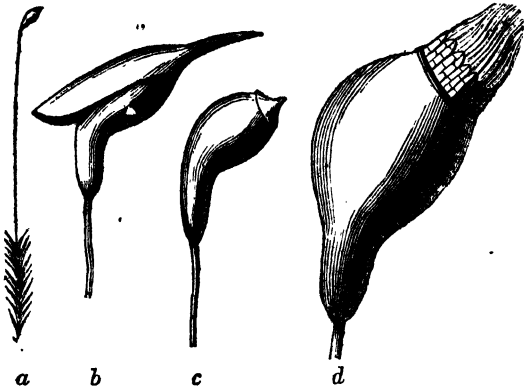
* Hooker and Taylor, *Muscologia Britannica.*

Fig. 121.*



The *sporule case* or theca (also called capsule) of Mosses is a little oblong or urn-shaped body, which in a few cases is *sessile*, but is usually borne upon a filiform *fruit-stalk* or *seta* (*fig.* 121, *a*.). The base of the fruit-stalk is commonly surrounded by a few leaves of a different form and lesser size than the ordinary leaves of the stem: these are collectively named the *perichæth*. At its first appearance the theca is sessile, either at the summit of the stem or in the midst of the leaves, and furnished with a membranous covering. Soon the seta elongates, and the membrane is torn from its base and carried up with the theca, which it covers like an extinguisher (*fig.* 121, *b*.). This is termed a *calyptra*.

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* ***Fig.* 121, *a*, represents a plant of *Meesia longiseta*, of the natural size: *b*, represents the theca with its calyptra, considerably magnified: *c*, the theca after the calyptra is removed, exhibiting the lid: *d*, the theca still more magnified, with its peristome brought into view by the removal of the lid.**

When torn away equally from its base, so as to resemble an extinguisher or a tall cap, it is said to be *mitriform:* if split up on one side, as in *fig.* 121, *b*, it is said to be *dimidiate* or *halved.*

The removal of the calyptra brings to view the summit of the theca with its mouth closed by the *operculum* or *lid* (*fig.* 121, *c.*), which is differently shaped in different species, being sometimes nearly flat, sometimes conical, and occasionally prolonged at the summit into a beak. When the theca is fully ripe, the lid is thrown off by means of a curious contrivance for the purpose, and its mouth is exposed. The structure of the *stoma* or mouth of the theca affords the principal generic characters (196) in Mosses. It is usually furnished with a beautiful fringe, composed of teeth or hair-like processes, called the *peristome* (*fig.* 121, *d.*). The peristome is sometimes *single*, and in other cases *double*, or provided with an outer and an inner fringe. The processes of the outer fringe are termed *teeth;* those of the inner *ciliæ.* The outer series belong to the external, and the inner to the internal coat of the theca. It is worthy of remark, that the number of teeth in the peristome is either four, which is the smallest number, or some multiple of four. A single genus, *Tetraphis*, has a peristome of four teeth, and another, met with only in tropical countries, viz: *Octoblepharis*, has eight, as the name denotes; sixteen is a frequent number; thirty-two still more so; and a few have sixty-four; but no Moss is known with any intermediate number of teeth.

The peristome is very hygrometric, the teeth expanding and turning outwards in dry weather so as to expose the open mouth of the theca; but if breathed upon, the moisture of the breath, merely, causes them to bend inwards and form an arch over the orifice of the theca. A manifest object of the fringe is to detach the lid in due season, and also to aid in the dispersion of the sporules in dry weather, and in wet weather to protect them from moisture and prevent their escape.

The teeth or bristles of the inner peristome are sometimes more or less connected by a membrane. In the common Hair-cap Moss (*Polytrichum commune*), the peristome consists of a strong membrane, closing the mouth of the theca.

The peristome, however, is not always present, several Mosses having none at all; in this case the mouth is said to be naked, as in Sphagnum or Peat-Moss.

There is an expansion of the fruit-stalk, just at the base of the theca in some Mosses, termed an *apophysis.* It exists in the Hair-cap Moss, and in several others. A little column, which commonly occupies the axis of the theca, is called the *columella.*

The sporules of Mosses consist of a fine greenish powder filling the theca; from which Mosses may be raised as from seeds.

There is another set of organs in Mosses, the nature of which is not well understood. They are small, oblong and stalked grains, usually placed at the summit of the stem, commonly preceding the apparatus we have just described; when old, they are known to contain a granular matter. Hence Hedwig, who took the theca with the accompanying parts for a pistillate flower, considered the former to be anthers. This view is opposed by Sprengel, who has seen these supposed anthers fall from the stem, take root, and produce new plants. This has been observed in several species. He therefore, with good reason, considers them to be buds, or little bulbs, like those borne in the axils of the leaves of Lilium bulbiferum, and on the fronds of several Ferns; and he also remarks that, as is the case with other bulbiferous plants, those which produce these bodies plentifully seldom bear fruit; and that it is only where the soil is particularly good, and the air moist, that they produce buds and fruit together. The common Hair-cap Moss bears these bodies in the greatest abundance.

The germination of the sporules of Mosses is entirely different from that of any true seeds, and substantially agrees with that of the Equisetaceæ. Pellucid fibres are emitted indifferently from any part of the sporule; some of these remain beneath the surface, others rise into the air, become green and present the appearance of a Conferva, and finally a mass of these fibres grow together and produce the stem. This subject has been admirably investigated by Mr. Drummond * (the author of the *Letters to a Naturalist*, and a popular botanical treatise), who succeeded in raising more than 30 different kinds of Mosses from their sporules. "In *Funaria hygrometrica*," Mr. Drummond remarks, "processes made their appearance on the second day after sowing, in the form of pellucid points, evidently growing out of the substance of the seed. On the fourth day, each minute plant had from one to three of these appendages, each appendage growing out of a different part of the brown covering of the seed."

"On the seventh day they appeared, when magnified with the highest power of a compound microscope, to be about two lines in length, obtuse and jointed; and, when growing in water, having some green-colored particles appearing within them, similar to what we find deposited in the cells of the leaves in a more advanced state of the plant. But I observed that some of the articulated filaments in the pots of earth, penetrated the soil in every direction, and formed the roots; those filaments only being of a green color which were growing on the surface. On the tenth day I found these filaments beginning to throw out branches. In a fortnight the surface of the pots appeared as if covered with green velvet, from the numerous branched filaments that clothed every part of the soil."

"I find the time which Mosses remain in the Conferva state, before they produce their true leaves, to vary considerably in different species, and even in the same species under different circumstances. When regularly supplied with moisture, *Funaria hygrometrica, Didymodon purpureum*, and some others, produce their true leaves in about three weeks from the time of sowing." *Polytrichum aloides*, which is very common on banks, remains about four months in this state, and has been described and figured as a plant of the Conferva tribe; and the same thing has happened to several other Mosses. These green filaments, in the species just referred to, are present at all seasons, forming a delicate velvety covering for the soil in which the plant grows.

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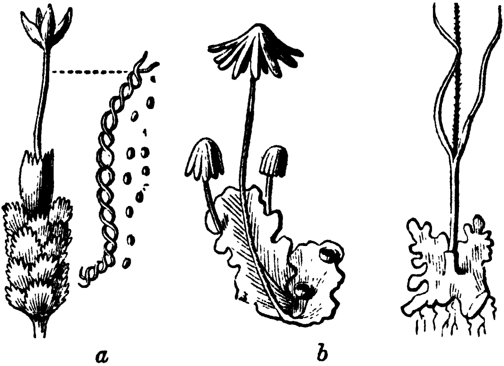
* *Trans. Linnæan Society*, XIII., p. 24, et seq.

VI. Hepaticæ. *Hepatic Mosses. Liverworts.*

Fig. 122.



187. This is a tribe of humble, moss-like plants, usually growing in tufts and patches, on the ground, or on trees or rocks, in damp and shady places. They are intermediate between the Mosses and Lichens, the leafy kinds resembling the former, and those which have a foliaceous disk instead of stem and leaves, agreeing with the latter family. They are wholly composed of loose cellular tissue; and their leaves, if leaves they may be termed, are always destitute of frame-work or nerves.

Jungermannia, the largest genus of this tribe, presents the greatest resemblance to the true Mosses; although the capsule or theca of the former has no lid, but splits into 4 pieces when mature, and the sporules it contains are intermixed with elastic spiral filaments, termed *elaters* (*fig.* 122, *a.*). Some species also exhibit minute spherical bodies, supported on short stalks, which have been termed anthers.

In Anthoceros (*fig.* 122, *c.*), the theca splits into two valves, exhibiting a central columella, to which the sporules are attached by means of very short straight filaments.

In Marchantia, or Liverwort, (*fig.* 122, *b.*), the place of stem and leaves is supplied by a flat and lobed frond, attached to the ground by numerous slender fibres emitted from its lower surface. The upper surface is green, and furnished with breathing-pores, which were first noticed by Prof. Hooker. The thecæ are here attached to the lower surface of a hemispherical or conical stalked receptacle, which is in one species entire, and in another deeply cut into 8 or 10 lobes, spreading like an umbrella. Similar receptacles in some species bear other bodies imbedded in their substance, which have been called anthers. Little open cups appear on the surface of the frond, containing green bodies, supposed to be analogous to buds, as they are capable of producing new plants.

When the thecæ are matured, they open at the extremity and emit a great number of sporules, intermixed with *elaters*, similar to those of Jungermannia. These elaters consist of a single spiral fibre, or more commonly of two filaments twisted spirally in opposite directions. They are elastic and very hygrometric, coiling and uncoiling with the variations of moisture or dryness of the atmosphere.* The only office they

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* Mirbel, in his Elém. du Phys. Vég. et Botanique (1815), I. p. 398, describes these filaments as membranous, diaphanous tubes, containing two threads spirally twisted in opposite directions ; but he at the same time expresses his opinion that this appearance may be an optical illusion. In his recent investigations, however, (as published in his incomparable memoir on the structure of Marchantia) than which none have thrown so much light upon the mysteries of vegetable organization, Mirbel has proved that these filaments are formed of single elongated cellules, which at first do not differ from the other cellules of the plant except in shape: their parieties are thin, entire, diaphanous, and colorless; but they soon begin to thicken, lose their transparency, and are marked throughout their whole length by two parallel spiral striæ. Having attained their full growth, each tube splits throughout at these striæ, and is thus transformed into two interlaced threads, spirally coiled in opposite directions, which at length assume a rusty yellow color.

This metamorphosis, continues Mirbel, was so complete, that if I perform, so far as we know, is to aid in the dispersion of the sporules.

Mirbel has given an interesting account of the manner in which the sporules of Marchantia vegetate, which was briefly noticed in another place (p. 7.). It will be observed that the developement of a new plant by sporules is essentially the same in all Flowerless plants, so far as they have yet been noticed.

VII. CHARACEÆ. *The Chara Tribe.*

188. The Chara tribe consists of submersed water-plants, having slender jointed stems, destitute of leaves, but furnished with whorled branches resembling the stem. There are only a few species, but these abound in stagnant water. Several kinds have the power of fixing so large a quantity of carbonate of lime in their tissue, that the plant retains its form when all the vegetable matter is destroyed. This is not an external incrustation from calcareous waters, since the matter is deposited beneath the cuticle, and evidently originates from within, as was observed by Dr. Greville. While, therefore, Equisetum retains a quantity of silex but no lime, even when growing in calcareous earth, Chara, from some peculiarity of its economy, accumulates the latter in its tissue and rejects the former.

Another interesting circumstance respecting these plants is, that in them was first observed the motion of the fluid contained in the articulations of the stem. The joints are elongated cellules. If we place a portion of this stem under a good microscope, having removed the calcareous incrustation if it have any, a current will be distinctly seen in each joint, flowing down one side and returning up the other, at the rate, in *Chara Vul-*

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had not followed these changes, step by step, I could not venture to affirm here that these two filaments were primarily a simple cellule: but the fact is constant; and I am convinced that whoever will repeat these observations with the determination of suffering nothing to escape him which it is possible to see, will arrive at the same results as mine. *Mirbel, Mem. sur le Marchantia,* p. 49, pl. viii. fig. 71, 72, 73.

garis, of about two lines per minute. The motion is rendered evident by the minute green granules which float in the transparent fluid, and follow the course of the currents. This circulation, according to Treviranus, is instantly checked by the application of a few drops of alcohol, or by any laceration of the tube. It sometimes stops of itself, and then goes on again after a brief interval. Each cellule has a movement of its own, independent of those above or below it; and if a cellule be divided by a ligature passed around it, a separate movement is seen in each of the divisions. Similar movements also have been repeatedly observed in the transparent stems of several aquatic Flowering plants, and in the fluid contained in hairs, such as those with which the filaments of the Spiderwort and Mullein are furnished.

The Charæ have two kinds of fructification. "The first is a *nucule*, which is sessile, oval, solitary, spirally striated, having a membranous covering, and the summit indistinctly cleft into five segments. The interior is filled with minute sporules. The second kind is a *globule*, or minute round body of a reddish color, composed externally of a number of triangular scales, which separate and produce its dehiscence. The interior is filled with a mass of elastic, transversely undulate filaments. The scales are composed of radiating, hollow tubes, partly filled with minute, colored, spherical granules, which freely escape when the tubes are injured: their nature is wholly unknown, and, I believe, hitherto unnoticed."* These colored granules, Dr. Greville remarks in another place, are exactly similar to the sporules of many cryptogamous plants.

It will be perceived that very little is known of the structure of these plants. Linnæus placed them at one time among Cryptogamous, and afterwards with Phænogamous plants, where several botanists still retain them. They are now, however, usually considered as Flowerless plants, and placed near the Algæ, of which, in the opinion of some eminent botanists, they are but a section.

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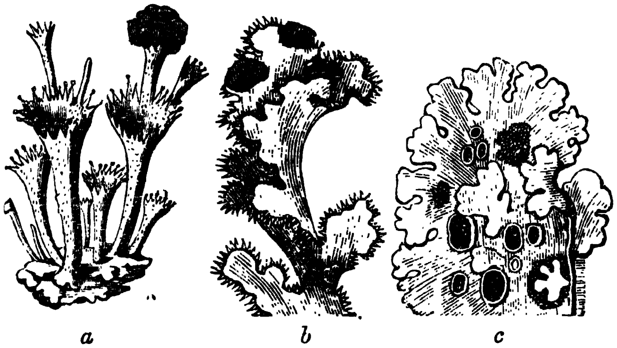
* Greville, *Flora Edinensis*, *introd.* p. 17.

VIII. Lichenes. *Lichenes.*

Fig. 123.



189. We have now approached the very confines of the vegetable kingdom, and meet with forms totally different from ordinary plants. We no longer find leaves, stem, or any distinct axis of growth. The three tribes, Lichenes, Fungi, and Algæ, into which the leafless and cellular Flowerless plants are usually divided, each exhibit forms of much complexity, and others of the greatest possible simplicity; so that it is impossible to say which tribe should commence and which should close the series. Our notice of these families must be extremely brief and cursory. Many botanists have devoted a great part of their lives to the study of each of these tribes, and yet none of them are well understood.

It is almost impossible to convey in words an adequate idea of the great variety of forms under which Lichens occur. Yet they are very familiar objects, and there is scarcely a trunk of a tree, a rock, or an old wall, that does not present them to our view, in varied forms and great abundance. Many species resemble thin crusts, and are inseparable from the rock or tree on which they grow. Others consist of granular or pulverulent matter, and some are composed of a gelatinous substance. A great number of Lichens are flat and broad, usually lobed expansions, of a crustaceous texture, fixed by their lower surface to the trunk, rock, or soil on which they grow, and bearing on their superior surface excrescences, shields, or spots, in which the reproductive sporules are imbedded. The main substance of the Lichen is termed the *frond* or *thallus:* the portions which contain sporules are called *apothecia.* The apothecia according to their appearance receive different names. A *scutellum* is an apothecium, or shield, with an elevated rim. Convex excrescences without a rim are called *tubercles.* *Soredia* are heaps of powdery matter on any part of the thallus; and there are a great number of similar terms, which render the nomenclature of the tribe excessively difficult. Many crustaceous Lichens are attached by their whole surface to the bodies on which they are found; several kinds, growing on the ground, are furnished with slender root-like fibres on their margins and under surface, which are conspicuous in the genus Borrera.

A considerable number of Lichens resemble shrubs or corallines in miniature, growing erect on the ground or on decaying logs, &c. *Ex.* Cenomyce. (*fig.* 123, *a.*) In these the thallus is generally small, and the stalk-like processes which elevate the fructification are termed *podetia.* The podetia are sometimes cup-shaped at the extremity, bearing several apothecia on the margin. The cup is termed a *scypha.* Several Lichens consist of long, filiform, and entangled branches, pendent from the boughs of trees, to which they give a hoary aspect. (*Ex.* Usnea, Alectoria.) The fructification in these genera consists of little circular shields at the extremity of the branches.

The centre of the stem, in the last-mentioned kinds, is occupied by a filamentous substance, and the surface is composed of a cortical matter, or a kind of bark. In the flat species the lower surface is dry, filamentous, or imperfectly cellular and colorless; and the upper, which is the living or growing surface, assumes a great variety of colors. In their origin, Lichens, according to Eschweiler, are mere Confervæ (191) developed in humidity, forming, when the under part dies from the diminution of moisture, a crust which ultimately becomes the basis of the plant. Hence Lichens exhibit two parts: viz. a dead tissue, which forms the basis or bed, and living cellules, which are the vegetating part; every portion of which is capable of becoming reproductive matter.

Lichens are widely distributed over the world, and abound especially in cold climates, thriving vigorously where few other plants are capable of withstanding the cold. In the polar regions and on the lofty mountains of temperate climates, they extend to the verge of perpetual snow. They are not confined, however, to any particular climate or degree of latitude, but "wherever there occur mould, stones, rocks, or trees, Lichens are sure to be found." A recent writer on Lichens estimates the number actually known at 2400.

Many crustaceous species contain so large a quantity of gelatinous matter, that they have been employed as articles of food. One of these is the Iceland Moss (*fig.* 123, *b.*) of the shops, once much used in medicine, which contains, according to Berzelius, about 80 per cent. of a gelatinous or amylaceous substance, and is, therefore, highly nutritive. It is a common article of food in Iceland, being dried and made into a cake or boiled with milk, and eaten with thankfulness by the natives; who confess "that a bountiful Providence sends them bread out of the very stones." Several species of Gyrophora, called by the Canadian hunters *Tripe de roche*, are used by them for food when they can get nothing better. The common Cenomyce rangiferina, or Rein-deer Moss, forms the winter food of that animal.

The *Orchall*, or *Argol* of dyers, which yields a fine purple colour, and the *Cud-bear*, are different species of Lichen.

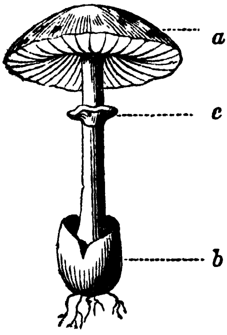
The crustaceous Lichens are found, in many instances, to contain a large quantity of oxalic acid, amounting in some cases to 30 per cent. or more, of their weight. This acid, acting chemically on the calcareous rocks on which these species are often found, decomposes the surface, and enables them to imbed themselves more firmly. Thus we also perceive that, through the agency of this apparently insignificant tribe of plants, the sterile rock becomes prepared for the maintenance of vegetables of higher organization.

IX. FUNGI. *The Mushroom tribe.*

190. Fungi are nearly related to Lichens, by a number of intermediate forms which have been sometimes referred to the one tribe and sometimes to the other; and to avoid which difficulty, have even been separated into a distinct tribe intermediate between the two. The Fungi are also connected with Algæ by a number of filamentous species, which only differ from the latter tribe by growing in the air instead of under water. Fungi have no proper frond or thallus: they are never green, although presenting a great variety of other colors; and, unlike Lichens, they grow upon dead trunks, and other decomposing vegetable or animal matter, rather than on living trees. Thus we observe a partially decayed branch or trunk will have the bark of the living side covered with Lichens, and the dead side with Fungi. They never grow upon the face of rocks, nor upon the earth unless the soil abounds in decaying vegetables.

The Agarics, or true Mushrooms, are better known than the other forms of this extensive tribe. They consist of an umbrella-shaped body, the cap or *pileus* (*fig.* 124, *a*,), the under surface of which is provided with thin radiating expansions, termed gills or *lamellæ* (*hymenium*), among which the sporules are situated. The stalk which elevates the pileus is called the *stipes*. In an early state, the whole is enveloped by a membranous integument, which is afterwards torn open by the elongation of the stipe; this is is termed the *volva* or *wrapper;* and its remains are observable at the foot of the stipe, as in *fig.* 124, *b*. Several species have a delicate

Fig. 124.



fringe or *veil*, which connects the margin of the pileus with the stem; this is destroyed by the expansion of the pileus as it approaches maturity, and a remnant is sometimes left in the form of a ring (*annulus*) around the stipe (*fig*. 124, *c*.). In Boletus, the under surface of the pileus is furnished with minute tubes instead of gills; and other species have the gills or pores on the upper instead of the lower surface. In Hydnum, the peridium consists of soft spines or teeth. The Lycoperdons or Puff-balls, are round masses of cellular tissue, enveloped with a fleshy covering (*peridium*), which opens by a hole at the summit, or splits into several pieces; the whole interior is filled with little bags (*sporidia*), which, when ripe, emit the fine sporules they contain in large quantities, having the appearance of smoke. Mucor, Mucedo, &c., those minute filaments, or tufted fugacious bodies, which appear in damp and dark places, on all decaying animal or vegetable substances, are the simplest forms of Fungi, and perhaps of all vegetation. Of this nature is the mould which forms on the binding of books in damp and close situations, that upon bread, cheese, &c., as also the mould which appears on the walls of damp cellars, and the various kinds of mildew or blight. These plants consist of simple or branching threads, variously interwoven, formed of minute cellules placed end to end. In some kinds, the sporules are included in the terminal joint inflated into a head; some exhibit scattered sporules on their outer surface; but in many no sporules have been detected.

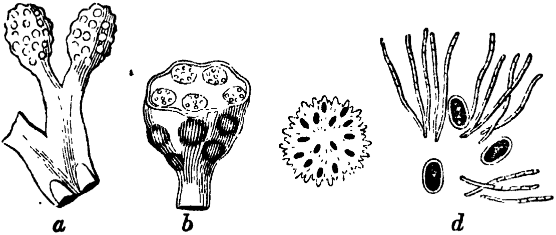
There is another section of Fungi, which are truly parasitic, originating beneath the cuticle of living plants, through which they finally burst. Of this nature is the *rust* of grain, and, in the opinion of many, the *smut* of corn, &c., and the *ergot* of rye and wheat. Possibly a great number of these appearances, which have been described as parasitic Fungi, are diseased states of the integuments.

"Some writers have questioned the propriety of considering Fungi as plants, and have proposed to establish them as an independent kingdom, equally distinct from animals and vegetables; others have entertained doubts of their being more than mere fortuitous developements of vegetable matter, called into action by special conditions of light, heat, earth, and air—doubts which have been caused by some remarkable circumstances, the most material of which are the following: they grow with a rapidity unknown in other plants, acquiring the volume of many inches in a single night, and are frequently meteoric, that is, spring up after storms, or only in particular states of the atmosphere. It is possible to increase particular species with certainty, by an ascertained mixture of organic and inorganic matter, exposed to well-known atmospheric conditions, as is proved by the process adopted by gardeners for obtaining Agaricus campestris; a process so certain, that no one ever saw any other kind of Agaricus produced in mushroom-beds. This could not happen if the Mushrooms sprang from seeds or sporules floating in the air, as in that case many species would necessarily be mixed together. They are often produced constantly upon the same kind of matter and upon nothing else, such as the species that are parasitic upon leaves; all of which is strong evidence of the production of Fungi being accidental, and not analogous to that of perfect plants. Fries, however, whose opinion must have great weight in all questions relating to Fungi, argues against these notions in the following manner: 'Their sporules are so infinitely small (in a single individual of Reticularia maxima I have counted above 10,000), so subtile (they are scarcely visible to the naked eye, and often resemble thin smoke), so light (raised, perhaps, by evaporation into the atmosphere), and are dispersed in so many ways (by the attraction of the sun, by insects, wind, elasticity, adhesion, &c.), that it is difficult to conceive a place from which they can be excluded.' I give his words as nearly as possible, because they may be considered the sum of all that has to be urged against the doctrine of equivocal generation in Fungi; but without admitting, by any means, so much force in his statement as is required to set the question at rest. In short, it is no answer to such arguments as those just adverted to."*

The number of species, if they be species, of Fungi is almost incalculable. Between four and five thousand are described. In Sweden, within the compass of a square furlong, where the number of Flowering plants was 420, and of Lichens and Algæ 430, Fries discovered more than 2,000 species of Fungi.

X. ALGÆ. *Sea-weeds, &c.*

Fig. 125.†



191. This order consists of the sea-weeds of the ocean, and the green, floating, scum-like substances of stagnant fresh water. These plants are either delicate, thread-like bodies, or cylindrical and branching, or membranous, or somewhat leaf-like bodies, or of a mixture of all these forms. Their structure is homogeneous throughout, and therefore the whole plant takes the name of *frond* or *thallus*. In their consistence the Sea-weeds are sometimes leathery or cartilaginous, many are composed of delicate and pellucid membranes, others of soft and pliable or elastic threads, and several kinds consist of a tremulous jelly. They exhibit the

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* Lindley, *Introduction to the Natural System of Botany*, p. 330.

† Fucus vesiculosus: *a*, a portion of the frond with tubercles: *b*, a section of a magnified tubercle (*capsule*), exhibiting the thecæ: *c*, a theca greatly magnified: *d*, the contents of a theca, viz. a few sporules mingled with threads, very highly magnified—all from Greville's *Algæ Britannicæ*.

greatest variety in size; many species being excessively minute, scarcely even visible to the naked eye; and from this they are found of all sizes up to the length of 30 or 40 feet, which is attained by several species. The longest of all Algæ, though at the same time comparatively slender, is a species of Macrocystis, which, it is reported by navigators, attains the length of from 500 to 1500 feet. Its stem is furnished with many air-bladders, without which it would be impossible for the plant to support its enormous length in the water, since the base is no thicker than the finger, and the upper branches are as slender as common packthread.*

This family of plants exhibits a great variety and brilliancy of color. Almost every hue is to be found among them, but the predominant ones are green, red, and brown.

The organs of fructification in this tribe are very simple. They consist of sporules, scattered in the interior or on the surface of the frond, or in tubercles, which are either free or imbedded in the frond, or in distinct capsules or thecæ (*sporidia*). The vesicles or air-bladders, with which many species are furnished, should not be mistaken for fruit-bearing organs. They are portions of the frond inflated with air, supposed to be of use in keeping the frond afloat.

About 1500 species of Algæ are known to botanists, and from the situation in which these plants grow, it is probable that a very small portion of the existing species have been detected. The Flora of the ocean seems to be nearly as extensive as that of the dry land. We know nothing of the purposes which Algæ subserve in nature, but they are applied by man to many important uses. The Dulse and Laver are valued articles of food, and many other kinds are eaten in different parts of the world. Some undetermined species furnish the material of which the celebrated edible swallow-nests of India are composed; of which one kind is sold for nearly its weight in gold. Iodine is yielded by almost every marine Alga, but most abundantly by several species of Fucus and Laminaria. Chondrus crispus, (called in Ireland *Carrageen moss*, which also grows on our own coast,) is converted into size; it also yields a fine jelly for invalids, and is often used in the composition of *Blanc-mange.* Until recently, the greatest part of the soda of commerce was furnished by the ashes of Sea-weeds.

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* Greville, *Algæ Britannicæ, introd.* p. 18.

192. In conclusion, we may advert to an opinion entertained, at this day, by several most distinguished botanists, which originated, if we mistake not, with Fries, a celebrated Swedish writer on Fungi. These authors suggest that there are no definite limits between Lichens, Fungi, and Algæ: that the same vegetable matter which, called into action on the earth, with sufficient light and air, &c., produces a Lichen, will, in moisture on decaying organized substances, become a Fungus; or, if developed under water, exhibit the form of an Alga. Thus the matter, which, at its first appearance, is a minute cobwebby or jelly-like substance, becomes, upon an exposed wall, a Lichen, in a dark cellar, a Fungus, upon a living plant, a parasitic Fungus, and in water, a Conferva. No Fungus grows under water, and no Lichen is either aquatic, or found growing in dark places. Fries says that he has seen several Algæ, so called while surcharged with water, perfect shields in air and sunshine, and turn out true and well-known Lichens.

Respecting Fungi, we have already said that the limits of that tribe, between Lichens on the one hand, and Algæ on the other, are undistinguishable. Seedling Mosses, Equisetums, &c., have been mistaken for Confervæ or Conferva-like Fungi, but their true nature is manifest by subsequent developement. If our means of observation were increased, it is possible that we should meet with characters for distinguishing these plants in any stage of growth, wherever any real distinction exists.

It is through the Algæ that the transition from the vegetable to the animal kingdom is supposed to take place; many of the small and thread-like species, or at least bodies described as species, of Algæ having been proved to be nothing but congeries of minute amimalculæ strung end to end. Some of these extraordinary productions, which are, to all appearance, filamentous vegetables in the earlier period of their existence, produce, instead of buds or sporules, little microscopic animalcules, which, after exhibiting a variety of rapid, and apparently voluntary, movements for a considerable time, at length become filamentous Algæ. Several Oscillatorias and Ulvas, with all the appearance of plants, exhibit active oscilatory movements. A species of Diatoma is known, consisting, like the other species, of hollow joints, having the form of a parallelogram: these portions are at first united with each other by their longest sides, but afterwards they separate, and are strung together by their extremities, so as to form a filiform tube. An adequate notice of this curious subject cannot be attempted here; but it may be confidently stated, that up to this time the absolute limits of the vegetable and animal kingdoms are undistinguishable.

CHAPTER VI.

OF THE CLASSIFICATION OF PLANTS.

SECT. I. *Of the Principles of Classification in general: Classes, Orders, Genera, Species, &c.*

193. The whole science of Botany rests on the foundation of vegetable organography and physiology; and for this reason the botanical student should in the first place direct his attention to the study of plants as organized and living beings, and become familiar with all the ordinary forms of structure. To facilitate this object has thus far been the design of the present treatise. The vegetable kingdom is next to be considered in another point of view, viz: as composed of a great number of forms, distinct from each other, but exhibiting various degrees of resemblance; and here the object is to distinguish these forms or individuals from each other, and to note both their differences and resemblances; or, in other words, to describe and classify them. Without this department of the science, botany could have no existence as a branch of natural history, and the knowledge already accumulated concerning the 60 or 80,000 species of plants known to inhabit our globe could not be definitely expressed, or in any way rendered accessible to others. Consequently, classifications of some sort have been devised from the earliest times, varying with the amount and precision of the actual knowledge of plants, of which they form a tolerably accurate criterion. A complete classification carried to its full extent, will accordingly be found to embody our existing knowledge of plants, and to indicate all the various degrees of resemblance or diversity observable among them.

194. Two methods, having different objects in view, have been followed in classifying plants. The one is called an *artificial*, and the other a *natural* method. The object of the first is merely to furnish the means

of readily recognizing individuals, and arriving at their names; the second, with this object likewise in view, proposes moreover to arrange plants, so that those most resembling each other shall stand side by side, and form groups by themselves; which groups are also to be arranged according to their mutual affinities into larger groups, and these again into still larger; all of which are to be disposed in the order indicated by nature. This method, accordingly, if perfectly carried out in practice, must express both the near and the more remote relations established by nature between the individuals of the vegetable kingdom.

An artificial method is easily contrived, as it may be founded on the diversities of form, &c., presented by one or two organs; its application only requiring a knowledge of structure sufficient for the observation of these diversities. On the other hand, *the* natural method (for there can be only one) is not contrived, but discovered; and, as it expresses the affinities and analogies imprinted by nature upon the members of the vegetable kingdom, it cannot be said to be wholly perfected until all existing plants are discovered, and properly described and arranged. An artificial method might therefore have been expected to prevail in the infancy of the science; but the discovery and adoption of the natural system appears to be the necessary result of the gradual accumulation of knowledge, and a more scrutinizing study of vegetable structure.

There is one point common to both these methods, viz: a provision for expressing the various degrees of affinity which plants present, by subdividing the whole vegetable kingdom into groups of different degrees of importance; the subordinate being comprised within the more general ones. These groups, which receive the same names in all classifications, are chiefly the following, beginning with the most important, viz:

Classes,
 Sub-classes,
  Orders,
   Genera,
    (Sub-genera),
     Species.

The vegetable kingdom taken as a whole, is in the first place conceived to be divided into two or more groups, the plants included in each agreeing with one another in certain general particulars, in which they are contrasted with those of the other groups: these primary divisions are termed *Classes*. By observing other characters less general than those we have employed in the formation of classes, the latter may be divided into subordinate groups, called *Sub-classes.* Continuing this process we in the same manner divide a sub-class into subordinate groups, called *Orders* (and also Families or Tribes); the analysis of an order furnishes *Genera;* and a genus includes one or more *Species;* the latter being the assemblage of all the individuals which resemble each other more than the individuals of any other group, agreeing indeed in every important particular.

Genera and species are nearly the same in all existing methods, the only artificial system in use being in that respect natural in as great a degree as the character of the orders and classes will permit. The difference principally consists in the arrangement of the genera, and the formation of the higher groups. We may, therefore, more especially state what is meant by species, genera, orders, &c. without allusion to any particular mode of classification.

195. Vegetables come under the cognizance of our senses only as individuals. Every plant complete in its parts, and distinct and separate from all others, whatever may be its origin, is an *individual.* The first degree of association observable in individuals, gives us the idea of species. If several individuals be raised from the seed of any plant, we observe that the new plants, although perhaps slightly differing among themselves in height, color, or other unimportant particulars, yet resemble each other and the parent plant much more closely than any other plants. These again, when they ripen seeds, are capable of reproducing other similar individuals. A *species,* accordingly, is defined to be the assemblage of all the indi-

viduals which resemble each other in all important particulars, and reproduce similar individuals by seed.*

Any considerable change in the ordinary state or appearance of a species is termed a *variety.* These arise for the most part from two causes, viz: the influence of external circumstances, and the crossing of races. Thus, as to the first-named cause, many species are capable of growing in almost every diversity of soil and situation, in consequence of which they undergo considerable changes in appearance. If a plant grows in more shady places than usual, it has a tendency to become more pale, slender, and feeble than is common to the species; if it has an unusual exposure, it is subject to modifications of an opposite kind; becoming more stout, firm, and deeply colored.

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* It is sometimes said that species have no existence in nature; and this view is commonly taken of genera, orders, and other groups. In one sense both these opinions are correct: Nature presents to our view nothing but individuals, but these are created with certain resemblances and dissimilarities in the structure, form, color, &c. of their organs. The *reunion* of these individuals by their most obvious and striking resemblances, gives the idea of species, by their less striking but more general resemblances, that of genera, and so on. We do not hesitate to say of all the horses in the world that they form a single species, although scarcely two individuals can be found exactly alike in every respect. Neither will any one hesitate to admit that the ass and the zebra form two species, perfectly distinct from each other and from the horse; and yet the three have certain common characters by which we at once recognize them as belonging to a single genus.

The fact that botanists often differ in opinion as to what are species, is no evidence against the existence or non-permanence of species, or the correctness of our definition. We are often under the necessity of judging from probable evidence, founding opinions upon characters which may occasionally deceive us; where one botanist recognises a species, another sees a variety merely, and vice versa. But should what we are accustomed to regard as a single species be proved to comprise two or more species; or, on the other hand, should nearly all the North American species, as they are considered, of Sagittaria, prove to be a single species modified by local circumstances (as is by no means unlikely), the idea of species would not be at all affected by our failures in practically distinguishing them.

The faculty of nicely discriminating species is a good test of the skill of a botanist, requiring as it does much experience, combined with habits of close observation, and a just appreciation of the value of characters.

A plant growing in a cold climate becomes smaller in all its parts, does not so regularly perfect its fruit, and the flowers are less odorous and paler in hue; whereas in a warm climate its stems become larger and more woody and leafy, the colors of the flowers more lively, and the odors and other sensible properties more intense. The influence of humidity produces numerous diversities. Plants which are pubescent in a dry soil, become glabrous when growing in very wet places; their stems usually elongating, and their leaves becoming larger. The influence of soil and cultivation in the production of varieties is too well known to require notice. By modifying the circumstances under which varieties occur, they may usually be made to revert to the ordinary form of the species, but they sometimes retain their peculiarities with great constancy under every mode of treatment. Such plants are perhaps true species, although they often differ from the species to which they are conceived to belong in such minor particulars only, that they are thought hardly to deserve that rank.

It is well known that the pollen of one species will often fertilize the ovules of other species of the same genus, and that the seeds thus produced give rise to individuals of an intermediate character, but which are unable to perpetuate themselves by seed, or if they have that power, lose it in the second or third generation. A hybrid may, however, be rendered fertile by the application of the pollen of either of the plants from which it originated; but in such case the new plant assumes the characters of the plant which furnished the pollen. Nearly allied plants of the same genus can alone be made to hybridize. The different species of Strawberry, the Pelargoniums or Cape Geraniums, the Lily, &c. intermix very freely; but the Apple and Pear, although species of the same genus, cannot be made to fertilize each other; and the same is true of the Currant and Gooseberry.

These monsters, however prized by florists, not being natural productions, can have no place allotted to them in a botanical treatise. They assuredly are not varieties, yet by intermixing with the plants from which they sprang, they probably originated the varieties (or *races*) capable of perpetuation by seed, so often presented by cultivated plants (*Ex.* Wheat, Peas, Beans, Cauliflowers, &c.). Ordinary varieties differ from these in being for the most part permanent by extension, but not by seed. Hybrids are very rarely produced by wild plants. I know of no instance of their spontaneous production by any truly native plants in North America, and only three or four cases of the kind are mentioned by European botanists. They are much more common among cultivated and domesticated plants. Along road-sides we frequently observe a hybrid between the two naturalized species of Vervain (*Verbena hastata* and *urticifolia*); and in a single locality I have noticed the greatest profusion of hybrids between Verbascum Lychnitis and the common Mullein (*V. Thapsus*). The species of the latter genus show a greater tendency to hybridize than almost any other.

196. A *genus* is a group of species all essentially agreeing in the structure of their organs, and more or less resembling each other in general appearance. The genus may be taken as the *type*, from which, by slight modifications of structure, form, &c., the species it comprises may be conceived to arise: but it is more philosophical to deduce the idea of a genus synthetically, by the assemblage of nearly-related species, just as we obtain the idea of species from the assemblage of similar individuals. In this view genera are certainly founded in nature, and not unfrequently they are even more obvious than species; as in the Rose, Birch, Willow, Oak, &c., in which the genus is at once recognized by every observer, but all the skill of the botanist is often required to distinguish the species. This view is not materially affected by the fact that botanists often disagree as to what are genera: they only differ as to the rank which certain characters marked by nature should hold in our classifications. Thus, some botanists divide the Honeysuckles into three genera, but others unite them into one, thinking

that the characters common to the whole exceed in value those peculiar to each group. Linnæus considered all the Geraniums as forming a single genus, including three subordinate groups; whereas succeeding botanists have elevated these groups to the rank of genera.

In very natural families, however, that is, where the species all very strongly resemble each other in structure and general appearance (*Ex.* Umbelliferæ, Cruciferæ, Labiatæ, Gramineæ, &c.), the genera are in one sense artificial, being in such cases convenient subdivisions of the tribe for the sake of forming groups of species having the same structure; or, in other words, we are obliged to establish them upon less important characters than in other families, and consequently experience greater difficulty in defining their limits. Botanists differ in such cases in their estimate of genera according to the degree of importance they attach to these characters, which must be in some respects arbitrary. Genera, as established in books, may, therefore, be expected to vary with the progress of our knowledge; but this is productive of little practical inconvenience.

When the species of a genus are capable of being arranged into two or more well-marked groups, the latter are termed *sub-genera,* or little genera. Thus the Honeysuckles (*Lonicera,*) are naturally divided into two sections (Lonicera proper and Xylosteum), which might, if it were thought proper, be elevated to the rank of genera.* If such divisions be not very distinct, or marked by any particular diversity of structure, they receive the name of *sections.* A genus often contains a single species only.

197. *Orders* are groups of genera founded upon some characteristic traits, which vary with the mode of classification adopted. An *artificial order* consists of

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* It clearly amounts to nearly the same thing, in fact, whether we consider the genus *Scirpus* of Linnæus to comprise several sub-genera, or with most modern authors consider the latter as independent genera, the whole (with one or two others) forming a little tribe or group of genera.

a number of genera necessarily agreeing only in the single character assumed as the basis of the classification. A *natural order*, *family*, or *tribe*, may be considered as a great genus, formed by the association of kindred genera, in the same way that a genus is formed by the assemblage of kindred species. The Ferns, Mosses, Grasses, Palms, Umbelliferæ, Cruciferæ, &c., are marked instances of this kind. An order is sometimes composed of genera agreeing in a few important characters, though differing in minor particulars, so as to present a regular gradation from one extremity of the order to the other. The Ranunculaceæ, or Crow-foot tribe, is a good example of this kind; the plants of which it is composed exhibiting such diversity in appearance, that they could not possibly be included in a single genus, and yet they all agree in the most important characters.

A natural order may sometimes be divided into two or more subordinate groups of genera, which bear the same relation to the order that sub-genera do to genera: these are termed *sub-orders*. Thus, the order Rosaceæ includes several sub-orders, such as the Rose tribe proper, the Apple tribe, the Cherry, or Peach tribe, &c.

198. *Classes*, the most general of all divisions, are formed by the association of orders having certain characters in common. *Sub-classes* bear the same relation to classes that sub-orders do to orders.

The same order of division is adopted in all botanical classifications; these observations, therefore, form a proper introduction to the consideration of the two principal methods of arrangement, which are next to occupy our attention.

SECT. II. *Of Artificial Systems.*

199. The object proposed by an artificial system of arrangement is to furnish a convenient mode of ascertaining the name of a plant. It may be likened to a dictionary, in which words are arranged alphabetically; adjacent words having no necessary agreement, except

in commencing with the same letters. In fact, an artificial system is to botany what an ordinary dictionary is to a language, offering a key to the requisite information concerning any given word, without professing to indicate the principles or analogies of the language.

The great Linnæus, who was the first to distinguish between an artificial and a natural classification, contrived, with great ingenuity and good taste, the artificial system which bears his name, and which, by its simplicity, elegance, and general applicability, became so deservedly popular, and, prevailing nearly to the exclusion of all others, effected a complete revolution in the science.

The fundamental principles of the Linnæan system are exceedingly simple and easily understood; to which circumstance, perhaps, its principal charm may be ascribed. Soon after the present view respecting the office of the stamens and pistils had been triumphantly established, Linnæus conceived the plan of a classification of plants, founded upon the modifications in number, situation, connexion, &c., of these important organs. This he successfully accomplished, and presented to the world, first in his *Flora Lapponica*, and several years afterwards in the more extensive *Species Plantarum*.

The classes of the Linnæan System, 24 in number, are wholly founded upon characters drawn from the stamens; and the characters adopted are all of an obvious kind, having relation to their number, situation, proportion, &c.

The first eleven classes are characterized by the number of the stamens, and are distinguished by names of Greek derivation, expressive of these characters. Thus:

Class 1. MONANDRIA; comprises all plants with perfect flowers, furnished with a single stamen.
2. DIANDRIA; comprises all such plants, with two stamens only.
3. TRIANDRIA; with three stamens.
4. TETRANDRIA; with four stamens.

5. Pentandria; with five stamens.
6. Hexandria; with six stamens.
7. Heptandria; with seven stamens.
8. Octandria; with eight stamens.
9. Enneandria; with nine stamens.
10. Decandria; with ten stamens.
11. Dodecandria; with twelve to nineteen stamens.*

The distinctions of the first eleven classes, it will be seen, rest upon the number of the stamens alone, but they are moreover restricted to plants with perfect flowers, having distinct, unconnected stamens.

The two succeeding classes derive their characters from the number and insertion of the stamens.

12. Icosandria, comprises the plants bearing flowers with 20 or more stamens, standing on (or rather adherent to) the calyx. *Ex.* the Apple, Cherry, &c.
13. Polyandria; with 20 or more stamens, not adherent to the calyx (*i. e. hypogynous*). *Ex.* the Poppy.

The two succeeding classes are founded upon the relative length of the stamens, viz.

14. Didynamia; comprising plants whose flowers present two long and two shorter stamens, as in Mint and most plants with labiate corollas; and—
15. Tetradynamia; those with four long and two short stamens. *Ex.* the Mustard. The names of these two classes are derived from the Greek numerals δις, *twice*, and τετρα, *four*, joined to δυναμις, *power;* the long stamens being supposed to be the most powerful.

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* The names of these several classes, and the two succeeding ones, are formed by prefixing the proper Greek numerals to *andria* (from ανηρ), used metaphorically for stamen.

Four classes, founded on the connexion of the stamens with each other, follow these, viz:

16. Monadelphia; including all plants whose flowers bear stamens with the filaments united into a single set or tube, forming a single brotherhood, as the name denotes. *Ex.* Mallow.
17. Diadelphia; with stamens united by their filaments into two sets, or brotherhoods. *Ex.* Pea.
18. Polyadelphia; with stamens united by their filaments into more than two sets.—A small class with few good N. American examples.
19. Syngenesia;[*] stamens with their anthers united into a ring or tube. *Ex.* the Thistle, and Sun-flower.

The next class is founded on the adhesion of the stamens to the pistil.

20. Gynandria; includes all flowers in which the stamens (apparently) grow out of the pistil, as the name denotes. *Ex.* Orchis, Ladies-Slipper.

The three succeeding classes are characterized by the separation of the stamens and pistils; the flowers being perfect in all the preceding classes.

21. Monœcia; has the stamens and pistils in separate flowers, but both growing on the same plant, or as the name denotes, both dwelling in one house. *Ex.* Oak, Indian Corn.
22. Diœcia; has the stamens and pistils not only in separate flowers, but on different individuals (in two households, as the name expresses it) *Ex.* Willow, Hop.
23. Polygamia; has the stamens and pistils separate in some flowers, and united in others, either all on the same, or on two or three different individuals.

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[*] From συν, and γινομαι, to arise, or grow together.

The remaining class comprises those plants whose flowers, if they may be so called, exhibit neither stamens nor pistils; including what are now named Flowerless plants. These Linnæus united under the name of

24. CRYPTOGAMIA; meaning that the essential organs of the flower are concealed from view.

We here present the classes of the artificial system as they were originally established by Linnæus. It is, however, proper to remark that several modifications have been from time to time proposed by succeeding botanists. Thus, some authors have reduced their number, by abolishing the eleventh, the eighteenth, and the twenty-third, distributing the plants they comprise among the other classes. These changes may, on the whole, be considered as improvements, although their adoption renders it necessary slightly to modify other parts of the system, so as to embrace the plants of the rejected classes.

The arrangement and leading characters of the classes may be advantageously exhibited in a synoptical view as follows.

SYNOPTICAL VIEW

OF THE

LINNÆAN CLASSES.

PLANTS having

- stamens & pistils manifest,
  - both found in the same flower,
    - stamens separate from the pistils,
      - unconnected with each other,
        - of equal length,
          - stamens 1 . . . . 1. MONANDRIA.
          - “ 2 . . . . 2. DIANDRIA.
          - “ 3 . . . . 3. TRIANDRIA.
          - “ 4 . . . . 4. TETRANDRIA.
          - “ 5 . . . . 5. PENTANDRIA.
          - “ 6 . . . . 6. HEXANDRIA.
          - “ 7 . . . . 7. HEPTANDRIA.
          - “ 8 . . . . 8. OCTANDRIA.
          - “ 9 . . . . 9. ENNEANDRIA.
          - “ 10 . . . . 10. DECANDRIA.
          - “ 11—19 . . . . 11. DODECANDRIA.
          - “ 20 or more, adherent with the calyx 12. ICOSANDRIA.
          - “ 20 or more, not adherent to the calyx 13. POLYANDRIA.
        - of unequal length,
          - 2 long and 2 short stamens . . . . . 14. DIDYNAMIA.
          - 4 long and 2 short stamens . . . . . 15. TETRADYNAMIA.
      - connected with each other
        - by their filaments in a single set . . . . 16. MONADELPHIA.
        - by their filaments in 2 sets . . . . . 17. DIADELPHIA.
        - by their filament in more than two sets . . 18. POLYADELPHIA.
        - by their anthers . . . . 19 SYNGENESIA.
    - stamens adherent to the pistil, ... 20. GYNANDRIA.
  - in separate flowers, ...
    - in the same individuals . . . . 21. MONŒCIA.
    - in different individuals . . . . 22. DIŒCIA.
    - some of the flowers perfect, others separated in the same, or two or three different individuals 23. POLYGAMIA.
- the stamens and pistils concealed, or none. . . . . 24. CRYPTOGAMIA.

The orders of the Linnæan system are in the first 13 classes founded on the number of the styles, or of the stigmas when the styles are wanting. They are named by prefixing the proper Greek numerals to *gynia*, used metaphorically for pistil.

1.	MONOGYNIA;	1 style or sessile stigma.
2.	DIGYNIA;	2 styles or sessile stigmas.
3.	TRIGYNIA;	3 " " "
4.	TETRAGYNIA;	4 " " "
5.	PENTAGYNIA;	5 " " "
†6.	HEXAGYNIA;	6 " " "
†7.	HEPTAGYNIA;	7 " " "
†8.	OCTAGYNIA;	8 " " "
†9.	ENNEAGYNIA;	9 " " "
10.	DECAGYNIA;	10 " " "
11.	DODECAGYNIA;	12 or thereabouts.
12.	POLYGYNIA;	more than 12.

Those marked thus (†) are of very unusual occurrence. It must be kept in mind that the foregoing orders are applicable to the first 13 classes alone. Those of the remaining classes are differently characterized.

Thus the 14th class, *Didynamia*, has 2 orders, founded on the fruit, and named and characterized as follows :

1. GYMNOSPERMIA (meaning naked seeds). Seeds naked, mostly 4.
2. ANGIOSPERMIA (meaning covered seeds). Seeds enclosed in a seed-vessel, usually numerous.

We have several times had occasion to remark that the so-called naked seeds of Linnæus are now well known to be small one-seeded fruits.

The 15th class, *Tetradynamia*, has also two peculiar orders, distinguished by the form of the fruit.

1. SILICULOSA. Fruit a silicle (*fig.* 106), or roundish pod.
2. SILIQUOSA. Fruit a silique (*fig.* 105).

The orders of the 16th, 17th, and 18th classes are founded on the number of stamens, that is on the characters of the first 13 classes, whose names they bear. Thus the Mallow, which belongs to the 16th class, *Monadelphia*, has more than 20 stamens, and accordingly belongs to the order *Polyandria* of that class.

The 19th, class, *Syngenesia*, includes 5 orders characterized by the nature of the florets, whether perfect, separated, or barren.

1. POLYGAMIA ÆQUALIS, has all the florets perfect, or furnished both with stamens and pistils. *Ex.* the Thistle.
2. POLYGAMIA SUPERFLUA, has the florets of the disk perfect, and those of the ray pistillate only; all, however, usually ripening fruit. *Ex.* Aster.
3. POLYGAMIA FRUSTRANEA, has the florets of the disk perfect; those of the ray bearing neither stamens nor pistils (at least in a well-formed state), and therefore not ripening seeds. *Ex.* the Sunflower.
4. POLYGAMIA NECESSARIA; has the florets of the disk with stamens only, the stigmas being imperfect; those of the ray with pistils only. *Ex.* Silphium, Parthenium.
5. POLYGAMIA SEGREGATA, has all the florets perfect, but each has a well-formed calyx, all being as usual enclosed by an involucre, called by Linnæan botanists a common calyx. *Ex.* Elephantopus, Echinops.

Linnæus added a sixth order to the above, called POLYGAMIA MONOGAMIA, to include several plants with simple flowers and united anthers, such as Viola and Lobelia; but succeeding botanists have transferred them to Pentandria monogyma, for no very satisfactory reason, since Linnæus did not intend his system to exhibit natural affinities.

The orders of the 20th, 21st, and 22d, classes, are, like those of the 16th, 17th, and 18th, distinguished by the characters of the preceding classes, that is, for the most part, by the number of the stamens.

The 23d class, *Polygamia*, has three orders, founded on the characters of the classes immediately preceding.

1. MONŒCIA, has both separated and perfect flowers on the same individual.
2. DIŒCIA, when one individual bears the perfect, and another the two kinds of separated flowers.
3. TRIŒCIA, when one bears the perfect, a second the staminate, and a third the pistillate flowers.

The 24th class, *Cryptogamia*, exhibiting no characters analogous to those employed for orders in the other classes, Linnæus divided into four *natural orders*, viz: Ferns, Mosses, Algæ, and Fungi. To these were soon added two others, viz: the Hepaticæ or Liverworts, and the Lichens; and now that Flowerless plants have been examined more attentively as to their structure and affinities, several additional orders have been established. A brief account of these is given in Chapter V., to which the student is referred.

200. It remains to point out the method to be pursued by the student in ascertaining the name of an unknown plant by means of the artificial system of Linnæus. The system is so simple, in theory at least, that a few words will suffice for this purpose. We will suppose the student to have in his hands some Flora, or work containing descriptions of plants arranged according to this method, and that the plant before him for examination is a Lily. The first object is to ascertain the class to which the plant belongs; and this point is commonly of easy attainment. The tabular view given on page 298 exhibits the steps to be pursued in this investigation. In the first place we inquire, has the plant manifest stamens and pistils? This question being answered in the affirmative, the class Cryptogamia is excluded, and we next inquire whether the flowers are always perfect? i. e. furnished both with stamens and pistils. This being the case in the flowers before us, the 21st, 22d, and 23d classes are excluded; and the next step is to determine whether the stamens are adherent to, or separate from the pistil. Inspection decides for the latter; our plant, therefore, cannot belong to Gynandria, the 20th class. We accordingly inquire whether the stamens are themselves distinct and unconnected, or connected with each other? The stamens having no connection with each other, the 16th, 17th, 18th, and 19th classes are excluded; and we next inquire whether the stamens are of equal length? The inequality in the length of the stamens is not taken into consideration except their number be either four or six. The plant before us presents six stamens,

but being all of the same length, the 14th and 15th classes are excluded; and as they are fewer than twenty, we have only to count the stamens to ascertain the class, which we accordingly find to be the 6th, *Hexandria.* The order to which our plant belongs is found with equal readiness. The orders of this, and of all the first 13 classes, being founded on the number of styles, we have only to inspect the pistil to determine this point. Our plant has a single style, and therefore belongs to the first order, *Monogynia.* Thus far the investigation is unattended with difficulty and requires no skill; and all the knowledge necessarily attained, is the simple fact that the flowers of the plant under consideration have six stamens and a single pistil. The next step is to ascertain the genus to which our plant belongs; and here we meet with the chief difficulties n practice. The plan to be pursued, however, is abundantly plain. In the Flora, or work containing descriptions of plants, to which we must now refer, all he genera comprised in each order are arranged according to some convenient method, and their characters (*i. e.* the circumstances which distinguish each genus from all others of the same order) are enumerated. These characters are taken, for the most part, from the flower and fruit. Our plant is to be successively compared with these, and we find that although it exhibits many of the characters of several genera, yet it agrees n every respect with but one viz. LILIUM. We have thus ascertained the generic name of the plant under consideration, and it only remains to determine the species. For this purpose we compare our lant with the characters of the species enumerated nder the genus Lilium, and thus, if the plant be described in the work in our hands, we learn the specific ame in the same manner as that of the genus.

Further illustration is scarcely required in this place, since, by the examination of several flowers of different classes, a student, perfectly ignorant of botany, may fully comprehend the principles of the artificial system of Linnæus in a single day. To this simplicity in theory, and to the easy manner in which it generally nables a person unpractised in botany to learn the name and history of an unknown plant, the great popularity of this system is chiefly attributable. Its merits, therefore, are too obvious to need a more particular enumeration; for it is undeniable that it possesses many advantages; that it was far better adapted than any other to the state of the science at the time of its appearance, and that it has exerted a most important influence upon its progress. This is cheerfully conceded by the botanists of our own day, who, nevertheless, with one accord pronounce it to be wholly unsuited to the present state of the science. It is equally clear, however, that this system has many imperfections and difficulties, that its advantages have been very much over-rated by its admirers, who have often forgotten the objects it proposes to accomplish; and that it may fairly be doubted whether, on the whole, it possesses any decided advantage over a natural system, even in facility of application. To this subject, however, we shall have occasion to devote more particular attention.

It has been objected to the Linnæan system, that in very many instances it widely separates kindred plants, and as frequently brings together those wholly unlike each other in structure, appearance, properties, and indeed in every thing except the number or arrangement of their stamens and pistils. Thus, while the Mint, Balm, Horehound, and the major part of the Mint tribe, are placed in the class Didynamia, the Sage, the Water Horehound (*Lycopus*), the Mountain Mint, the Horse Mint (*Monarda*), &c. plants universally recognized, as their popular names denote, to belong to the same tribe, and agreeing with the preceding in every respect except in having but two stamens, are arranged in Diandria. If we turn to the tribe of Grasses, we find one (*Cinna*) in the class Monandria, the Sweet-scented vernal grass (*Anthoxanthum*) in Diandria; the major part of the tribe being in Triandria Digynia, while the Rice is arranged in Hexandria Digynia, the Gama grass and Indian corn are placed in Monœcia Triandria, by the side of the Sweet Fern and Cat-tail flag; and the Water-Oat (*Zizania*) stands in another order of the same class. Some authors, indeed, have placed most of these together in the class Triandria, but in this they openly disregard the principles of the system they profess to adopt. On the other hand, what considerations of convenience can reconcile the association of the Barberry and the Spiderwort, the Lily and the Bulrush in the same order? or the arrangement side by side of the Gentians, the Caraway, the Elms, and the Pigweeds, in one order; the Maple, the Cranberry and the garden Nasturtium in another; and the Cucumber, the Castor-oil plant, and the Pine in a third? To all this it may be answered, that the system does not profess to bring together plants which resemble each other, except in having the same number of stamens and pistils; but that it is intended to serve the same purpose as a dictionary, in which words having very different meanings, if formed of nearly the same letters, often stand together. So thought the great founder of the system, who was the first to distinguish between an artificial and a natural method; but several succeeding botanists, professing to adopt his system, nevertheless hesitate to term it artificial, or are unwilling to admit the possibility of its being superseded by a better.

Admitting, then, as we readily do, that no artificial system can be expected to furnish natural groups, and that the object of such an arrangement is attained when it provides a certain and easy method of ascertaining the species of an unknown plant, we proceed to show several cases in which the artificial system of Linnæus fails to accomplish even this result, owing to insuperable difficulties in the system itself; thus leading to uncertainty, error, and confusion, for which nothing but the study of the natural affinities of plants can furnish the corrective.

Firstly, when a plant has lost its stamens, though otherwise perfect in its parts, this system furnishes no means of classifying it, or even of taking the first step towards ascertaining its name. Or, if the student meet for the first time with the pistillate flowers only of a diœcious plant, the same difficulty occurs, for which the system furnishes no remedy. Again, should the stamens or pistils of an unknown plant undergo those curious transformations to which cultivated species are especially subject, forming double or monstrous flowers, the Linnæan botanist is brought to a stand, as in all the preceding cases: his system, founding its primary divisions on a single set of organs, furnishes no ulterior resource; and he is obliged, as a most ingenious advocate of the artificial system frankly admits,* "*to guess at a new plant from its natural resemblance to some known one*;" or, in other words, to betake himself to the study of the principles of the natural method to evade the difficulties of an artificial system.

Secondly, there is another perplexing difficulty of very common occurrence, arising from the irregularity in the number of stamens, styles, &c. in the several species of a natural genus, or in different individuals of the same species, or sometimes even in different flowers on the same individual. Where the number of parts, however, is not subject to variation, difficulties equally perplexing often occur in some other form. A genus not unfrequently comprehends some species with perfect flowers, while others are monœcious, diœcious, or polygamous. Some plants constantly exhibit united anthers, and yet are not referred to the class Syngenesia. Others have their stamens united into a single tube for a part of their length, and yet are not placed in Monadelphia; and Linnæus referred to Diadelphia a number of genera uniformly exhibiting monadelphous stamens.

Lest our view of these difficulties should appear to be exaggerated, we adduce a few examples.

The greater part of the species of Stellaria have 10 stamens, and Linnæus accordingly placed the genus in Decandria; but the common Chickweed (*S. media*), the species which of all others the student will probably first have occasion to examine, has usually five, often three, and very rarely as many as ten stamens. In this case how is the student, as yet ignorant of other species of the genus, to arrive at the knowledge of his plant? In early spring the botanical student will probably find along the margins of shady brooks, the Chrysosplenium Americanum, a humble but somewhat interesting plant with inconspicuous flowers. On examining the flower, he will probably observe only eight stamens; and if desirous of ascertaining its name by the artificial system, he will look for it in Octandria, where it will not be found. If the examination of the plant be carefully continued, he may possibly discover a flower with ten stamens, and thus be induced as a last resort to look in the class Decandria, where he will find the name of his plant. If he inquire why a plant so regularly producing eight stamens is placed in Decandria, the only answer to be given is, that two European species have generally ten stamens in their terminal flowers and eight in the remainder; and as Linnæus referred these to Decandria, our plant must be placed there also, although it very rarely exhibits as many as ten stamens in any of its flowers. The Rue, also, has ten stamens in the terminal flowers, which are the first to expand, but uniformly exhibits eight in all the others. No fixed rule can be framed for the distribution of such plants in the Linnæan classes.

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* Smith, *Introd. to Botany*, Am. Ed. p. 312.

All the North American species of the Vine are either polygamous or diœcious, yet they are placed in the class Pentandria because the European species are mostly perfect and pentandrous. All our species of Lobelia have united anthers and filaments, and should therefore, by the principles of the Linnæan classification, be placed in Syngenesia, where the student would naturally expect to find them; or if that class is to be restricted to compound flowers, this genus would seem to belong to Monadelphia; most botanists, however, retain it in Pentandria. We pass over such instances as those of the Milk-weed, the Dog's-bane, &c., which have two short styles and a single stigma, in which case we have no means of determining whether they should be placed in the order Monogynia or Digynia.

There are many analogous cases, arbitrarily settled by the usage of botanists in such a manner as to afford little aid to the unassisted student; who will not fail to perceive that the system is much more simple in theory than easy in practice. As the student advances, he no doubt overcomes many of these obstacles, not however by improving in the application of the principles of the system itself, but by disregarding them altogether. Thus, about eighteen species of Polygonum inhabit the Northern states, and this genus is so distinct in its character, that a student once acquainted with several species cannot fail to distinguish all the others as members of the same genus. Polygonum was placed by Linnæus in Octandria, but of the eighteen species just referred to, only eleven have 8 stamens, one has 9, three have 6, two have 5, and one has 7 stamens. Now, if the first species which the student has occasion to examine be octandrous, all will be clear and easy: if otherwise, the system leads him into inextricable difficulty. A catalogue of such anomalies may set him right, although this is no part of the system. If, after having attained a knowledge of one species of Polygonum, others of the same genus having 5, 6, or 7 stamens, fall into his hands, he refers them at once to their proper place, on account of the great resemblance they bear to that with which he is already acquainted; thus relying on the natural classification by affinities, in defiance of the principles of the Linnæan system.

The genus Phytolacca furnishes such a well-marked instance of the little dependence to be placed upon the the number of stamens and pistils as primary characters, that we advert to it here, although only a single species inhabits North America. Seven species of this genus are described in Sprengel's Systema Vegetabilium, viz:

1. *Phytolacca decandra* (the common Poke of this country), which has 10 stamens and 10 styles.
2. *P. Abyssinica*, which has 10 stamens and 5 styles.
3. P. *Bogotensis*, which has from 7 to 10 stamens and from 7 to 9 styles.
4. *P. octandra*, has, as its name denotes, 8 stamens and 8 styles.
5. *P. heptandra*, has 7 stamens and 6 styles.
6. *P. icosandra*, has 20 stamens and 10 styles.
7. *P. dioica*, has more than 20 stamens, which, as the name denotes, are separate from the pistils, and borne on different indivduals.

No two of these species, it will be observed, are referrible to the same Linnæan class and order; but, as they all really form a single genus, which of the seven is to have the pre-eminence? The genus was, we believe, originally established on *P. decandra*, and accordingly referred to Decandria Decacynia; the other species as they became known being set down as anomalies. We are aware that this is an extreme case, perhaps the most anomalous instance that could be adduced; yet we hesitate not to say that the number of exceptions and deviations from the principles of the artificial system is much greater than is generally supposed, and that the method does not possess the "universal applicability" for which its advocates contend.*

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* We subjoin, in illustration of this subject, the following table of exceptions, compiled from Torrey's Flora of the Northern and Middle states.

Linnæan Class or Order.	hole number genera in ea ss or order.	. of genera containing species at variance with the character of the class or order.
Monandria Monogynia,		1
Digynia,		2
Diandria,		2
Triandria Monogynia,		8
Digynia, .		12
Trigynia, .		1
Pentandria Monogynia,		10
Digynia,		10
Trigynia,		1
Polygynia,		1
Hexandria, . .		11
Heptandria, . .		1
Octandria, . .		3
Enneandria, . .		1
Decandria Monogynia,		5
Digynia, .		3
Trigynia,		2
Pentagynia,		4
	274	78

It appears from this table that out of 274 genera, the whole number in 18 orders, 78 genera, or nearly one-third of the whole number, con-

No one could be more fully aware of the insufficiency of an artificial system in botany, or could more highly appreciate the advantages of the natural method, than Linnæus himself; and the so-called Linnæan botanists, in whose estimate the former system leaves little to be desired, have quite mistaken the views of their great master and sadly misrepresented his opinions. While he framed an artificial system for the convenient arrangement of plants, justly considering it as the one best adapted for this purpose *at that day*, and indeed as the only available one in the then existing state of the science; he also gave a sketch of a natural method, explaining the principles on which the latter might be expected to rest, and pronounced the investigation of natural affinities to be the great object of his studies and the most important part of the science; considering the artificial system as a temporary expedient, which, however necessary at that day, would inevitably give place to the system of nature so soon as its fundamental principles should be discovered. It will not be deemed irrelevant to adduce more fully the testimony of Linnæus on this subject; since, in this country at least, the well-deserved fame of that distinguished naturalist is somewhat endangered by the eulogies and injudicious zeal of those who pretend to be his followers and exclusive admirers. Linnæus, with all his partiality for the system he himself invented, affirms *that the artificial method is but a substitute for the natural, to which it must, in due time, give place. The natural method*, he also states, *is and must be the principal object of the science; the elucidation of which is the first and ultimate aim of Botanists; to this end the labor of*

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tain species which are uniformly or commonly at variance with the class or order to which they are referred, thus presenting a much greater amount of exceptions than can be found in all natural families, not only of the district which the work embraces, but in the whole of North America. A similar analysis, compiled from a general Flora of North America according to this system would, we doubt not, exhibit a much greater proportion of exceptions.

A table of anomalous flowers appended to Pursh's Flora of North America, which the author thought necessary for the assistance of young botanists, consists of no less than eight pages.

the greatest Botanists should be diligently directed, and the merest fragments of this system should be carefully studied.—Though not yet discovered, it is held in high estimation by the wisest Botanists, while by the less learned it is thought to be of little consequence. For a long time, continues Linnæus, *I have labored to establish it: I have made many discoveries, but have not been able to perfect it; yet while I live I shall continue to labor for its completion.—In the mean time I have published what I have been able to discover; and whosoever will resolve the few plants which still remain shall be my magnus Apollo.—Those are the greatest Botanists who are able to correct, augment, and perfect this method; which those who are unqualified should not attempt.* *

It must now, we think, be conceded on all hands that the day anticipated by Linnæus has arrived, when the artificial system, having effected the object for which it was invented—that of serving as a temporary substitute for a natural system—is no longer needed; that it has, in fact, after accomplishing a great amount of good in its day, given place to another method equally convenient, and infinitely more philosophical as well as useful; and those who perpetuate its existence on account of the alleged facilities it presents for acquiring a mere knowledge of names with the least possible expenditure of thought, would do well to consider whether the respect due to the system of Linnæus, viewed in reference to the higher ends for which he himself intended it, be not compromised by permitting its degradation to purposes for which it was not originally designed.

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* While giving the substance of the views of Linnæus, we subjoin, for the satisfaction of the student, the exact words which he employs.

Perpetuum est quod methodus artificialis sit tantum naturalis succedanea, nec possit non cedere naturali.—*Class. plant. in præf.*

Methodus naturalis primus et ultimus finis Botanices est et erit.—*Phil. Bot.*

Primum et ultimum in hoc Botanicis desideratum est.—Summorum Botanicorum hodiernus labor in his sudat et desudare decet.—Methodi naturalis fragmenta studiosè inquirenda sunt.—*Phil. Bot.*

Primum et ultimum in parte systematica botanices quæsitum est methodus naturalis; hæc adeo a Botanicis minus doctis vili habita, a sapientioribus semper tanti æstimata adhuc licet detecta nondum.—*Class. plant.*

Diu et ego circa methodum naturalem inveniendam laboravi, bene multa quæ adderem obtinui, perficere non potui, continuaturus dum vixero; interim quæ novi proponam; qui paucas quæ restant bene absolvit plantas, erit mihi magnus Apollo.—*Class. plant.*

Emendent, augeant, perficiant hanc methodum qui possunt; desistant qui impares sunt; qui valent Botanici sunt eximii.—*Class. plant.*

About 60 years have elapsed since the death of Linnæus, during which period the science has undergone a revolution quite as complete as that effected by the great reformer of systematic botany himself. We have now a more perfect and intimate knowledge of the structure of plants, and so far understand the laws by which their external forms are modified, that natural groups may be defined as accurately as artificial assemblages; and thus the chief obstacles that impeded Linnæus are now surmounted. That many difficulties still remain is fully admitted; but assuredly nothing need prevent us "from using the powers we possess, and bringing the science to that state in which only it can be really useful or interesting to mankind."

SECT. III. *Of the Natural System.*

201. The classifications of Cæsalpinus, Ray, Tournefort, and others of the predecessors of Linnæus were attempts, imperfect indeed, to arrange plants according to their natural affinities. The natural classification of Linnæus was a more elaborate attempt of the same kind, but he was unable, in the then existing state of structural botany, to express in words the resemblances and affinities he recognized among plants, and accordingly left his groups without characters. The learned Bernard de Jussieu, a contemporary of Linnæus, devoted all his attention for many years to the discovery of a natural method of arrangement; and although he pub-

lished no system during his life-time yet whoever examines his distribution of genera into natural orders, as published by his nephew at the head of his own *Genera Plantarum*, will be surprised at the acuteness with which the natural affinities of plants were seized at that early age of botany. The first successful exposition of the natural system was given by the celebrated Ant. Laur. Jussieu, in his incomparable work on the Genera of Plants arranged in Natural Orders,* which was published in 1789. "This octavo volume," says Sir J. E. Smith, "was received by acclamation throughout Europe, and hailed as the most learned botanical work that had appeared since the Species Plantarum of Linnæus." From this period, the science of Botany has advanced with unexampled rapidity; and the labors of the greatest botanists of the age (among whom we may only advert to De Candolle, Brown, the late Richard, Martius, and Lindley,) have effected an entire change in the aspect of the science within the last forty years. We shall not attempt to give a history of its progress, but shall confine our remarks to a view of the principles of the natural system as now received.

202. The natural method of arrangement proposes to express the mutual affinities of plants as far as possible; and to effect this object, its classes and other divisions are founded, not upon a single character or set of characters, but upon several; no part of the vegetable being neglected. This method chiefly rests upon the relative value of characters; the most universal being employed for the grander assemblages, and the less general for subordinate divisions. These considerations need not be taken into account when we employ an artificial method, in which the leading characters assume a factitious importance, not necessarily, or indeed usually, correspondent to nature.

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* *Ant. Laur. de Jussieu, Genera Plantarum secundum Ordines Naturales disposita*, Paris, 1789. As only a single edition of this work has been published, it is now very scarce. Its author still survives at the advanced age of 88 years.

It accordingly becomes necessary to pass in review the several organs described in the preceding chapters, for the purpose of noticing the value of the characters they respectively furnish in a natural arrangement.

Every organic peculiarity in which plants differ or agree among themselves is a character. No circumstances of this kind should escape the notice of an accomplished botanist; but the comparative importance of these characters is, nevertheless, extremely different. The most general, or in other words, the most constant characters are of the highest, and those most restricted or inconstant are of the lowest value: the most general characters are, therefore, of the highest value for great divisions, such as classes, orders, &c.; and the less general for minor groups, such as genera and species. Thus, the presence of flowers and seeds is characteristic of the great class designated as Flowering plants; but this character, being common to the whole class, is of no use in its subdivisions. Less general characters furnished by these same organs, such as the structure of the flowers, seeds, &c., afford the best characters for subordinate divisions, although useless for the more general ones, and of no importance for distinguishing the genera or species of those groups from each other, because common to them all. The value of a character, therefore, depends upon the purpose to which it is to be applied. Of this we shall presently have several illustrations.

The permanence of a character also affects its rank; those which are most permanent being of the highest value, and those which are most variable of the lowest. Thus, the seed-vessel and the seed are produced year after year without perceptible variation, furnishing constant and permanent characters; but the color of the flowers, the surface of the leaves whether smooth or hairy, the height of the stem, &c., are liable to great variation; and, accordingly, much less dependence can be placed upon these characters.

The highest character presented by any organ is drawn from the consideration of its presence or absence. Thus, Vascular and Cellular plants are distinguished, the one by the presence, and the other by the absence of cellular tissue; Flowering and Flowerless plants by the presence or absence of flowers, &c.

The characters next in importance are those furnished by the position or arrangement of any organ or set of organs. Thus, the two great groups into which Flowering plants are divided (33) are distinguished, the first (*Exogenæ*) by having the vascular tissue disposed in concentric rings around a common axis (the pith); and the second (*Endogenæ*) by having this tissue disposed in bundles, and not in zones. They are also distinguished by another character which is a consequence of the preceding, viz: the presence of medullary rays (36) in the former case; and their absence in the latter.

The seed, considered under the most important view, that of its presence or absence, furnishes characters for distinguishing the two primary classes already indicated. If we consider the embryo, or essential organ of the seed, under the view next in importance, viz: the situation of its parts, we find that the two sub-classes are characterized, the one by having the cotyledons opposite, the other by having them alternate (175). The situation of the embryo within the seed is also found to afford characters of a high rank.

Characters drawn from the form, connection, relative length, and relative number of organs, are next in importance; those furnished by the absolute number of parts, such as the number of stamens, pistils, seeds, &c., being usually of much less consequence. The abundance of any tissue, intensity of color or odor, the degree of pubescence, &c., are all characters of the lowest rank, being by themselves insufficient to distinguish species.

Linnæus thought that the organs of fructification furnished the most constant characters, and he accordingly admitted no others except in distinguishing species. We now know that anatomical structure furnishes those of the highest importance; but these are few, and as yet are scarcely used except for classes and sub-classes. The organs of vegetation, also, are now known to afford characters of as high rank as those of reproduction, and several which are even of greater importance; but the organs of reproduction furnish a greater variety of characters than all others, and these, accordingly, are most commonly employed for orders, genera, and even species.

The *Root* furnishes the fewest characters of all the organs of vegetation; and this is no doubt partly owing to the difficulty of examining it, and of preserving it in the herbarium. Its forms, although liable to great variation in cultivated plants, often furnish good characters for species.

The subterranean modifications of the stem, such as bulbs, tubers, cormi, and rhizomata, afford good characters for species, and occasionally for genera; but they are seldom of much importance in distinguishing orders.

The *Stem*, in its ordinary modifications, furnishes numerous characters of great importance. Its structure, whether Exogenous or Endogenous, distinguishes the two sub-classes of Flowering plants, as already observed. It is highly probable that the structure of the stem when more attentively considered, will be found to afford many characters for orders. Only a small number of such cases, however, are now known. All the plants of the Carolina Allspice tribe (*Calycantheæ*) have four imperfect centres of growth on the outside of the ordinary concentric circles of wood, exhibiting something like an instance of Exogenous and Endogenous growth combined in the same individual.* The peculiar structure of the woody tissue distinguishes the Coniferæ and Cycadeæ† even more unerringly than their flowers and fruit. Palms are known by their cylindrical stems with a terminal bud; Grasses by their cylindrical and hollow stems closed at the nodes; and square stems are almost universally found in the order Labiatæ, and that part of Rubiaceæ which comprises the Madder, Galium, &c. The figure of the stem is, however, commonly a character of species only; its direction, whether erect, decumbent, trailing, or climbing, also affords good characters for species; but its height, degree of robustness, of branching, &c., are frequently too variable to be depended upon, even for specific characters. The mode of branching often furnishes good characters, being connected with the position of the leaves and buds; yet this circumstance has hitherto been little attended to. *Spines*, being merely abortive branches, are rarely sufficiently constant to indicate more than varieties. The Pear, which produces spines when it grows wild, loses them in a cultivated state.

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* See Mirbel, in the *Annales des Sciences Naturales*, XIV. p. 367; and Lindley, *Introd. Nat. Syst.* Am. ed. p. 26.

† See note, on page 9.

The presence of *prickles, glands, scales, &c.* often serves to distinguish species, and the same may be said of pubescence; but, as has already been remarked, little or no dependence can be placed on the degree of pubescence; although the form of the hairs commonly furnishes good specific distinctions, and sometimes even those of genera or orders.

Leaves afford a great variety of characters of different degrees of importance. The outline or figure of the leaves furnishes excellent characters for species, although they must be employed with considerable latitude, for the same individual sometimes presents ovate, lanceolate, and even linear leaves; and as to division of margin, entire and pinnatified leaves are not very unusual in the same plant; a difference in these respects alone, unaccompanied by other marks, being hardly sufficient for indicating a species. The nature of the margin, however, sometimes assists in the determination of the genus or order to which a plant belongs. Thus, the Gentian tribe, the Myrtle tribe, all Rubiaceæ, and all Endogenous plants with a few exceptions, have entire leaves.

Simple and compound leaves are scarcely to be expected in the same genus, although several instances of the kind occur in Rosaceæ, and some other families.

The arrangement of leaves on the stem affords characters of high rank. Most Endogens have alternate leaves, but it is difficult to specify the prevalent form in Exogens. There are, however, only a small number of orders which present both opposite and alternate leaves. All Labiate plants, Rubiaceæ, Gentianeæ, the Pink tribe, and several others, uniformly have opposite leaves; the Ranunculaceæ, Cruciferæ, Umbelliferæ, Amentaceæ, &c. have constantly alternate leaves; while in the Pea tribe, the Poppy tribe, &c., the latter arrangement most commonly prevails. As to connection with the stem, it is observable that the leaves of Endogens never separate by an articulation, but decay without falling; while a true joint is formed, sooner or later, in all Exogenous plants.

A high order of characters is furnished by the venation of leaves, the two principal modes of veining (53) coinciding almost uniformly with the two sub-classes of Flowering plants; the subordinate modifications are also sometimes characteristic of orders. Thus the Mallow, Gourd, and Currant tribes exhibit the radiated form of veining; the Amentaceæ, &c. the feather-veined form; the Melastomaceæ (*Ex.* Rhexia) are characterized by the strong parallel veins or ribs, converging to the apex of the leaf, somewhat after the manner of Endogenæ; and the Myrtle tribe is distinguished by the presence of an intra-marginal vein, formed by the confluence of the veinlets just within the margin.

The presence of pellucid dots, observable when the leaf is held against the light, is of consequence as indicating a peculiar organization. This circumstance especially characterizes the Orange and Myrtle tribes, and is also observable in the Hypericineæ (*Ex.* St. John's-wort).

The presence or absence of *Stipules* affords important characters, the same order scarcely ever presenting both stipulate and exstipulate leaves. The form of stipules often distinguishes species, and sometimes even orders. Thus, Polygoneæ, the Buck-wheat tribe, (with the exception of Erigonum) is well characterized by the presence of ochreate stipules (*fig.* 38. *c.*).

Bracts, with which the floral organs may be said to commence, are seldom used except for distinguishing species; but in Gramineæ, where they exclusively constitute the floral envelopes, they furnish the principal generic, and also the most valuable specific characters. Bracts also furnish generic distinctions in Compositæ.

The different forms of *Inflorescence* afford excellent characters, some of specific, and others of generic importance. Thus, a spike and a head, a raceme and a panicle, &c., though not found in the same species, are often met with in different species of the same genus. But a corymb and a cyme, or a head and a glomerule, are not observed in the same genus; these forms respectively belonging to two very distinct modes of inflorescence. The inflorescence, also, occasionally furnishes obvious ordinal characters. Thus, all Amentaceæ bear catkins; all Coniferæ, strobiles; the anthodium is one of the characteristics of Compositæ, and the umbel of Umbelliferæ.

The *Floral Envelopes* furnish a great variety of characters. The mode of æstivation, of the calyx especially, is commonly of ordinal importance. Thus, the æstivation of the calyx is valvate in the Mallow tribe, in Tiliaceæ and all the nearly allied families, and imbricated in the Pink tribe, the Flax tribe, &c. The absolute number of sepals or petals is sometimes a character of considerable consequence. Thus, the numbers 3 and 6 are nearly universal in Endogens, and 5 is the prevalent number in Exogens; all Cruciferous plants have 4 sepals and 4 petals; and the presence of 2 sepals and 4 petals, or some multiple of that number, is characteristic of the Poppy tribe.

The various forms assumed by the *Calyx* afford good specific characters, and its more marked peculiarities are used for generic distinctions. The adhesion of the calyx-tube to the ovary, causing the latter organ to appear inferior, is usually a character of ordinal importance, only a few cases being known of a free and adherent calyx in the same family. The Saxifrage tribe, however, exhibits all degrees of this adhesion.

The presence or absence of the *Corolla* often distinguishes orders, but its absence is of comparatively little moment when the calyx is constantly present.

The two cases not uncommonly exist in the same genus (*Ex.* Clematis), and sometimes even in the same species (*Ex.* Isnardia palustris). The numerous diversities in texture, color, and odor, and the slighter modifications of form presented by the corolla, afford characters for species or varieties; its more important diversities in form, number of parts, connection with each other and cohesion with neighboring organs, furnish excellent generic distinctions. The union or distinctness of the petals sometimes conveniently distinguishes orders; but there are so many orders indifferently presenting both monopetalous and polypetalous corollas, that that no absolute dependence can be placed upon this circumstance as an ordinal character. Several orders are well distinguished by the peculiar form of the corolla. Thus, a papilionaceous corolla is never found except in the Pea tribe; a labiate corolla is nearly restricted to the Mint tribe (*Labiatæ*), and the Orchideæ, Polygaleæ, Fumariaceæ, &c., are respectively characterized by a peculiar irregular corolla, which at once distinguishes them.

The *Stamens*, whether viewed as to their insertion, connection, structure, relative length, number, &c., furnish characters of various degrees of importance. Their insertion, or situation with respect to other organs, affords valuable ordinal distinctions. Thus Ranunculaceæ, Cruciferæ, Papaveraceæ, &c., uniformly exhibit hypogynous stamens; Rosaceæ, Myrtaceæ, &c., perigynous stamens; and Umbelliferæ, epigynous stamens. As to the connection of their filaments, they are monadelphous in the Mallow tribe and several kindred families, diadelphous in the Pea tribe proper, with a few exceptions, such as Sophora where they are separate, and Lupinus where they are monadelphous. The suppression of a part of the stamens, causing an irregularity as to number or situation, also deserves to be noticed. Thus, the whole outer series is either suppressed, or transformed into scales or thread-like processes in the Primrose tribe, from which it happens that the stamens which do appear are opposite the petals. The suppression of the fifth stamen, and occasionally of two others, is seen in Scrophularineæ, Acanthaceæ, Labiatæ, Bignoniaceæ, &c.

The relative length of the stamens is commonly of little importance, except in the families last mentioned, where two stamens are almost invariably shorter when they are not entirely suppressed; and also in Cruciferæ, where of 6 stamens two are uniformly a little shorter than the others.

The union of the anthers into a short tube is a characteristic of Compositæ; one-celled anthers, opening by a slit along the upper edge, are seen in all Malvaceæ; each cell opens by a terminal pore in Ericineæ, Solanum, &c., and by valves in the Barberry and Laurel tribes.

Excellent ordinal distinctions are afforded by the manner in which the anther is connected with the filament. Thus, the anthers are versatile in Gramineæ, and erect in Cyperaceæ. The form of the pollen-grains is capable of being used for distinctive characters, but on account of the minuteness of these bodies they are seldom employed; their various modes of connection furnish sectional characters in Orchideæ, and ordinal characters in several families.

The *Pistil* affords many characters of great value. It is important to observe whether this organ be inferior or superior, or, in other words, adherent to the calyx or free from such adhesion. The value of this character has already been noticed. It is also of great consequence to observe whether the organ consists of one or several carpels. Thus, the Pea tribe exhibits a solitary simple pistil; and Cruciferæ, Capparideæ, and Fumariceæ present a compound pistil consisting of two united carpels, which an inexperienced botanist might easily mistake for a simple pistil. In Ranunculaceæ the pistils are usually separate, but in a few cases the same genus (*Ex*. Nigella, Delphinium) presents species with distinct and partially combined carpels. Apocarpous and syncarpous pistils, however, rarely occur in the same genus. The number of cells in the ovary, as indicating the composition of the pistil, generally affords generic distinctions, at least when the question rests between one and several-celled ovaries.

The *Style*, as to its relative or absolute length, form, &c. affords good specific characters, and sometimes those of genera. The *Stigma* likewise affords specific and generic distinctions, and occasionally those of orders. Thus, in the Pink tribe the stigmas occupy the whole inner surface of the style: in the Flax tribe, &c. they are capitate.

The *Ovules* afford excellent characters for orders and genera, both as to situation, whether erect or suspended, and also as to number, whether one, two, or several; their structure furnishes still more constant characters, which will be mentioned under seeds.

The *Fruit*, being the ripened pistil, the characters it affords are nearly of the same value as those of that organ, and several additional ones are also presented by the texture and dehiscence or indehiscence of the pericarp. The texture rarely furnishes unexceptionable ordinal characters, since membranous, woody, fleshy, and berry-like fruits are sometimes found in the same family, and even in the same genus; it, however, usually affords good generic characters, and must not be disregarded in the former view, making allowance for occasional exceptions. Dehiscent and indehiscent fruits often exist in the same family; as in Ranunculaceæ, in which Ranunculus, Clematis, &c., have an indehiscent, and the Columbine, Larkspur, &c., a dehiscent fruit. The mode of dehiscence is not always the same throughout the same family; and sometimes both the loculicidal and the septicidal dehiscence are met with in the same genus, as in Hypericum.

The *Seed*, which in itself unites the characters of an organ of reproduction and of vegetation, affords more important characters than any other single organ. The texture and appearance of its coverings sometimes serve to distinguish orders or genera, and very often furnish excellent, although commonly minute, characters for species. The presence or absence of *Albumen* is, with some qualifications, a most important character for distinguishing orders. The texture of the albumen, when this substance exists, is also taken into account. Thus, it is oily in the Poppy tribe, mealy in the Buck-wheat tribe, in Gramineæ, &c., horny in Rubiaceæ and Umbelliferæ; and ruminated in Anonaceæ and the Nutmeg tribe.

The *Embryo*, or miniature plant contained with a seed is found to afford characters of the highest importance. Its presence distinguishes Flowering from Flowerless plants; the want of one cotyledon distinguishes Exogenous from Endogenous plants; and its position with regard to the albumen distinguishes Gramineæ from Cyperaceæ. The Polygoneæ, Urticeæ, &c. are at once distinguished from kindred families by their orthotropous seeds; and no instance is known of the occurrence of anatropous and campulitropous seeds in the same order. It is true that these characters are often minute and somewhat difficult of observation, but their constancy renders them extremely useful. We have already observed, what we here take occasion to repeat, that in ordinary cases a mere inspection with a simple microscope will suffice to determine all the important points relative to the structure of a seed; and a little practice renders this kind of investigation as certain, and almost as easy, as the examination of the more conspicuous floral organs.

203. The object proposed by the natural system is to bring together into groups those plants which most resemble each other, not in a single character only, but in every essential point; so that a knowledge of any one individual of a group will give an adequate idea of the structure, habits, and general properties of the whole. The subordinate groups being combined into larger assemblages, and these again into still more comprehensive divisions, the whole vegetable kingdom is at length embraced in the general classification. Thus, as has already been observed, genera are groups of kindred species, orders are assemblages of kindred genera, and sub-classes and classes are vast assemblages of orders agreeing with each other in certain general and important characters. Supposing the mutual affinities of plants to be rightly understood, it will be borne in mind that these groups are really natural; but their relative value as compared with each other, as also the names used to designate them, cannot be fixed by any

absolute rule, and will be found accordingly to vary more or less with the progress of our knowledge, and with the views taken by different botanists, until the means of investigation are nearly exhausted. What our botanist considers as a single genus, another may divide into several, and vice versa; and the same may be said of the higher divisions. That this is an inconvenience in any science, although in a great degree unavoidable, is readily conceded; but it is not a very material one, neither does it prove, as students are at first sight apt to imagine, that the system itself is fluctuating and uncertain. Thus, it is quite immaterial whether the great group *Amentaceæ* be viewed as a single order, comprising the Willows, the Birches and Alders, the Bayberry, the Oaks and Chestnuts, &c., as so many sub-orders; or whether these be considered as several distinct but nearly related orders. The natural family of *Rosaceæ* exhibits another illustration of this kind. All the plants of this order have a general similarity in structure and appearance, and are properly considered as forming a separate group. We find, however, that this great assemblage is naturally divided into several well-marked minor sections. Thus, the genus which contains the Almond and Peach, and that comprising the Plum and Cherry, agree in having a single ovary, which in fruit becomes a drupe, in their bark yielding gum, and in the presence of prussic acid in the bark, leaves, and kernel of the fruit. The Apple, Pear, and Thorn, likewise agree in their pomaceous fruit and other obvious characters; and the Rose, the genus Rubus (comprising the Raspberry, Blackberry, &c.,) the Strawberry, and several other genera, compose a third group equally distinct from the two preceding. In this, as in the former example, some botanists view these groups as kindred orders, and others more judiciously consider them as sub-orders or sections of one great order. The same observations equally apply to genera, as already remarked. An attentive study of the relative value of characters will eventually lead to uniformity in this respect; and even at present the practical inconvenience is by no means great.

In the arrangement of plants according to the natural system, all the circumstances which indicate their mutual affinities should be duly considered, and hence no characters are to be disregarded. The leading principle in the formation of natural divisions is, that the highest and most general characters are to be employed for primary divisions, or classes; and the highest of those not so employed are appropriated to sub-classes; those next in importance and permanency to orders, and the still more subordinate or less permanent, to genera and species. Having given a sketch of the principal characters employed in botany, and briefly indicated their relative value, so far as the case will admit, we proceed to show their application in establishing and distinguishing those grand divisions of the vegetable kingdom which form the basis of the natural system.

204. It has already been shown that the vegetable kingdom, viewed as a great whole, is naturally divisible into two grand classes, called FLOWERING and FLOWERLESS plants: the one comprising the plants which produce flowers, the other those always destitute of these organs. This division is proved to be truly natural and of primary importance, by the uniform agreement which subsists among the plants of each class in the most important characters furnished both by the organs of reproduction and of vegetation. If we consider the organs of reproduction in Flowering plants with the view of ascertaining the rank of the characters they afford, bearing in mind that the value of a character is in direct proportion to the importance of the organ, we find that the calyx and corolla, serving chiefly for the protection of the stamens and pistils, and moreover being occasionally wanting, are consequently subordinate to the latter organs. The stamens are manifestly intended for the production of pollen, and the pollen for the fertilization of the ovary; when this end is accomplished, the stamens fall away:—the stamens are, accordingly, inferior in importance to the pistils. The pistil arrived at maturity consists of the seed-vessel and the seeds; the former serving merely for the protection of the latter. We thus arrive at the

seed as the most important of all the organs of reproduction, and which may therefore be expected to furnish the highest and most constant characters. This analysis may be carried a step further: the seed consists of the embryo, the albumen, and the integuments; of which the two latter are wholly subordinate to the former, the one being destined for the nourishment of the embryo at a particular season, and the other to enclose and protect the whole. The embryo, or rudiment of the new plant, is accordingly the essential organ of the seed, to which all others are subservient; it, moreover, necessarily exists in every perfect seed.

The reproductive organs of Flowerless plants, however varied in the several tribes and unlike true flowers in all, agree in producing bodies analogous to seeds, but which never contain an embryo. The vegetable kingdom may therefore, by means of the highest character (viz: the presence or absence) of the most important of the reproductive organs, be divided into two great groups (*Embryonateæ* and *Exembryonateæ* of Richard), perfectly corresponding in the plants they comprize, the one with Flowering, and the other with Flowerless plants.

So, also, the great classes *Cotyledones* and *Acotyledones* of Jussieu correspond with Flowering and Flowerless plants, since the latter producing no embryo are of course destitute of cotyledons. The names introduced by Jussieu for these grand divisions are objectionable, because the cotyledon is not an essential organ, and is wholly absent in some true embryos; as in the case of the Dodder (175).

If we notice the most important characters afforded by the organs of vegetation, we meet with further confirmation of the correctness of this division. Thus, Flowering plants exhibit (with very few exceptions) a distinct stem, root, and leaves; whereas these organs are more or less confounded with each other in Flowerless plants, except in a few of the higher tribes. The limits in this respect not being very well marked, we turn to the elementary organs, and find that Flowering plants are recognizable by the greater complexity of their organic structure, uniformly exhibiting the three kinds of elementary tissue. In Flowerless plants, on the other hand, we observe not only greater simplicity of organization, but the absolute want, or great diminution in quantity, of vascular and woody tissue. Assuming the fact of the absence of vascular tissue, or at least of spiral vessels, in Flowerless plants, several authors have applied the names of *Vascular* and *Cellular* plants to the primary divisions of the vegetable kingdom. We have, however, elsewhere observed, that although vascular tissue is found in all Flowering plants, and seems to be in some way necessarily connected with the production of flowers and seeds, yet there is not an abrupt change to a cellular organization, but a regular gradation is effected in this respect through several tribes of Flowerless plants. Although the structure of the stem is an almost unfailing index, yet the presence or absence of spiral vessels alone is not sufficient for this purpose; we therefore prefer to characterize the two grand classes essentially by the presence or absence of flowers and seeds.

205. Having thus established two great classes comprising the whole vegetable kingdom, the next step is to effect a division of each class into subordinate groups. The two grand assemblages into which Flowering plants are naturally divisible, have been already indicated in considering the structure of the stem (33, 40), leaves, flowers, and seeds (175), all of which afford characters for distinguishing them. Thus, as to the stem, the one sub-class presents the *Exogenous*, and the other the *Endogenous* structure, a character of high rank and remarkable uniformity; the former exhibits reticulated, and the latter parallel-veined leaves: as to the flower, the quinary arrangement prevails in the former, and the ternary in the latter case.

We have seen that Flowering and Flowerless plants may be distinguished by the presence or absence of the embryo; the same organ considered, not as to its presence or absence, but in regard to the situation and number of the cotyledons, also affords means for characterizing the sub-classes. Thus, all plants which exhibit the Exogenous structure, produce embryos with two opposite cotyledons; and all plants with the Endogenous structure, produce embryos with a single cotyledon, or (rarely) with two alternate with each other. We may accordingly designate the sub-classes of Flowering plants either by the names of DICOTYLEDONOUS and MONOCOTYLEDONOUS plants, or of EXOGENOUS and ENDOGENOUS plants, since the characters afforded by the embryo and by the structure of the stem, &c., wholly coincide in the plants they respectively comprise. The characters furnished by the cotyledons, however, are not only more difficult to distinguish, but are subject to several anomalies already mentioned: we therefore prefer to designate them by the names of EXOGENOUS and ENDOGENOUS plants, as proposed by De Candolle.

As Flowerless plants are destitute of embryo, and their organs of reproduction are exceedingly varied in different tribes, we are restricted to the organs of vegetation for the characters of sub-classes. We have already observed (181) that these plants may be arranged in two great groups, in some respects analogous to the Exogenous and Endogenous divisions of Flowering plants, viz: 1st, FIBRO-VASCULAR FLOWERLESS PLANTS; and 2d, CELLULAR FLOWERLESS PLANTS; the former comprising those which in part consist of vascular and woody tissue; the latter embracing all the lowest forms of vegetable organization, being wholly composed of cellular tissue.

206. For the purpose of presenting at a single view, the several peculiarities of the grand divisions of the vegetable kingdom mentioned in different parts of this work, we give an enumeration of the chief characteristics of the classes and sub-classes, in the form in which they are usually drawn up by botanical writers.

Such an enumeration of the essential distinguishing marks of a class, sub-class, or other group, is termed the *character* of the class, &c.

CLASS I.—FLOWERING PLANTS.

Phanerogamous or Phæogamous plants *of Linnæus.*—Cotyledones *of Jussieu.*—Embryonateæ *of Richard.*—Vasculares (partly) *of De Candolle.*

PLANTS composed of cellular tissue, woody fibre, and vessels (14'), provided with a root, stem, and leaves (14, 22, 26, 49); the whole invested with a distinct cuticle (15). FLOWERS essentially consisting of stamens and pistils (92), and generally furnished with floral envelopes. SEEDS attached to a placenta (137), composed of an embryo, or miniature plant, consisting of a rudimentary root and stem (radicle and plumule) and one or more cotyledons (174); the whole enclosed within an integument, and often provided with albumen (173); germination taking place at two fixed points, viz. the radicle and the plumule (174, 180).

SUB-CLASS I.

EXOGENOUS, OR DICOTYLEDONOUS PLANTS.

Dicotyledones *of Jussieu.*—Exogenæ *of De Candolle.*—Exorhirzeæ *of Richard.*

TRUNK more or less conical (39), generally branching, composed of bark, wood, and pith (33); the bark separable from the wood (34); the wood formed of concentric layers, enclosing the pith in the centre, and traversed by the medullary rays (35, 36), increasing in diameter by the deposition of new fibrous and vascular tissue between the old wood and the bark (39, 42). ROOT of the same structure as the stem, except in wanting the pith and spiral vessels (23). LEAVES either simple or compound (56), articulated with the stem (49), their veins branching and reticulated (53). STIPULES often present. FLOWERS most commonly exhibiting a quinary (sometimes a quaternary) arrangement of parts (109, 202). EMBRYO with a naked radicle (180), and two (rarely four or more) opposite cotyledons (175).

SUB-CLASS II.

ENDOGENOUS, OR MONOCOTYLEDONOUS PLANTS.

Monocotyledones *of Jussieu.*—Endogenæ (partly) *of De Candolle.*—Endorhizeæ *of Richard.*

TRUNK usually simple and cylindrical (40), (occasionally becoming conical by the development of axillary buds), composed of cellular tissue, in which fibro-vascular tissue is imbedded; the latter not arranged in concentric layers; no distinct pith; no medullary rays; no bark separable from the wood, but a smooth adherent rind (33, 40); increase in diameter effected by the deposition of new bundles of vessels and woody fibre towards the centre, the oldest and hardest wood being accordingly next the circumference (40, 42). Root exhibiting the same structure as the stem (23). LEAVES not articulated with the stem, but decaying without falling, mostly alternate (60), parallel-veined (53), entire, or rarely divided, but never truly compound (56). STIPULES none (62). FLOWERS mostly exhibiting a ternary arrangement of parts (109), the calyx and corolla frequently undistinguishable. EMBRYO with a single cotyledon, or sometimes with a second and smaller one alternate with the first (174); the radicle usually enclosed in a coleorhiza (180).

CLASS II.—FLOWERLESS PLANTS.

Cryptogamous plants *of Linnæus.*—Acotyledones *of Jussieu.*—Exembryonateæ *of Richard.*—Cellulares (partly) *of De Candolle.*

PLANTS chiefly composed of cellular tissue. never exhibiting stamens or pistils, and consequently not producing seeds. SPORULES not attached to a placenta, destitute of embryo, enclosed in cases called *thecæ*, or imbedded in the substance of the plant; germination occurring at no fixed point, but from any part of the sporule (181).

SUB-CLASS I.

FIBRO-VASCULAR FLOWERLESS PLANTS

Endogenæ Cryptogamæ *of De Candolle.*—Cellular plants § Ductulosæ *of Arnott.*—Cellulares Filicoideæ *of Lindley.*

FLOWERLESS PLANTS with leaves and a distinct trunk, composed of cellular, woody, and vascular tissue; the latter commonly appearing under the form of annular ducts. Mode of growth neither Exogenous nor Endogenous. Cuticle distinct.

SUB-CLASS II.

CELLULAR FLOWERLESS PLANTS.

Cellulares *of De Candolle.*—Cellulares Muscoideæ and Aphyllæ *of Lindley.*—Cellular plants § Eductulosæ *of Arnott.*

FLOWERLESS PLANTS wholly composed of cellular tissue. Stem and leaves usually confounded with each other, in which case there is no distinct axis of growth. Cuticle not distinct.

The first sub-class of Flowerless plants consists of four orders, viz: the Equisetaceæ (183), the Ferns (184), the Lycopodiaceæ (185, and the Marsileaceæ (186); the second comprises six orders, viz: the Mosses (186), the Hepaticæ (187), the Characeæ (188), the Lichens (189), the Fungi (190), and the Algæ (191).

The two sub-classes of Flowering plants each comprise a considerable number of orders, much too great to be enumerated here.

207. Primary divisions founded upon the most constant and important characters being thus established, the next step is to subdivide these into orders, or natural families; which, as we have already remarked, are groups of kindred genera, agreeing in certain important characters derived indifferently from every part of the plant. It must here be observed, that although no great difficulty is experienced in dividing the sub-classes into orders, nor in properly characterizing these assemblages and indicating their mutual alliances; yet it is, and probably ever will be, impossible to place them in such a series as that each order shall stand between the two it most nearly resembles. The obvious reason of this is, that each order (as well as every genus, species, &c.) possesses a great number of points of resemblance with several others, some of greater and some of less importance. It is manifest, however, that in a linear arrangement (which must of necessity be adopted in a book,) only one or two of these points of agreement can be indicated; and, moreover, the relative value of the affinites upon which we chiefly depend, is liable to be materially affected by the discovery of new plants, or the appreciation of new characters. Not uncommonly a family is found to present nearly the same degree of relationship with three or fourothers. Thus, the Poppy tribe is allied on the one hand to Rununculaceæ, and on the other to Cruciferæ; but it has also many points of resemblance with the Mandrake tribe (*Podophyllaceæ*), and with the Water-lily tribe (*Nymphæaceæ*). The Umbelliferous family affords another illustration of the kind, being about equally related to the Ginseng tribe (*Araliaceæ*), the Saxifrage tribe, and

the Ranunculaceæ; three families which, on account of their diversities as compared with each other, and the close affinities they respectively present to other orders, cannot be approximated in any natural arrangement.* Botanical writers, accordingly, dispose the orders of each grand division so as to indicate a few of their most obvious and important relationships alone, and different authors pursue different plans in this respect; yet the student will bear in mind that these linear arrangements form no part of the natural system itself, but are convenient contrivances for facilitating investigation, which may be wholly dispensed with when a truly natural method of grouping the orders shall be discovered. This end will perhaps be attained by the discovery of some constant characters of structure, establishing a truly natural subdivision of the Exogenæ and Endogenæ; or by the grouping of allied orders into aggregate or compound orders, as proposed by Brown,† and happily effected in several instances. When this is accomplished, the only practical inconvenience of the natural method will be obviated, and we may wholly dispense even with the slight remains of an artificial arrangement now admitted in our classifications.

Meanwhile, as divisions subordinate to the subclasses were required for practical convenience, Jussieu arranged the Dicotyledonous orders in four sections, viz: 1. *Apetalæ*, 2. *Monopetalæ*, 3. *Polypetalæ*, 4. *Diclines*; respectively comprising, the first those furnished with a calyx and destitute of corolla; the second those with a monopetalous corolla; the third those with unconnected petals; and the fourth those with separated, usually achlamydeous or naked, flowers. These convenient, although in many respects artificial, sections were subdivided into those with hypogynous, perigynous, and epigynous stamens. The Monocotyledonous orders were likewise classified by the insertion of the stamens;

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* The several affinities which the orders present among themselves may best be indicated by diagrams and charts of various kinds, as attempted by Agardh, De Candolle, &c.

† This has also been attempted by Bartling, and again quite recently by Lindley in his *Nixus Plantarum*; but neither attempt has proved so successful as could be desired.

while in the Acotyledones (Flowerless plants) on account of the small number of families, no such subdivisions were necessary.

De Candolle proposed a somewhat different distribution of the orders in the *Theorie Elémentaire*, which is adopted with some alteration in his *Prodromus*, as far as published, and in nearly all recent systematic works, arranged according to the natural method. It does not effect so great a subdivision as that of Jussieu, and, in fact, differs so little from the latter that the two may be very conveniently combined, as has been judiciously done by Mr. Arnott. De Candolle divides the Exogenæ, or Dicotyledonous plants into:

I. *Thalamifloræ;* in which the petals are distinct and hypogynous.
II. *Calycifloræ;* in which the petals, whether distinct or united, are always inserted on the calyx.
III. *Corollifloræ;* or those which have united and hypogynous petals, bearing the stamens.
IV. *Monochlamydæ;* or those with a simple perianth (or none).

These groups may be subdivided, if necessary, after the manner of Jussieu; as also may the Endogenæ, or Monocotyledonous plants, which De Candolle does not subdivide in any way. Lindley proposed to divide the latter sub-class into two sections, viz: ***Petaloideæ***, including all Endogens except Grasses and Sedges; and *Glumaceæ*, comprising those plants the flowers of which are destitute of a proper perianth, having in its place the imbricated bracteæ called glumes, &c. (*fig.* 62). They may be still farther subdivided into those with hypogynous, perigynous, and epigynous stamens; it being borne in mind that these divisions are in a great degree artificial, and may be expected ere long to give way to a more natural arrangement.

208. We are now prepared to indicate the method which the unitiated student should pursue in applying the principles of the natural system to the actual study of plants. Our end may, perhaps, be best attained by taking several common plants of different families as examples. The student should, when practicable, fol-

low these illustrations with specimens of the plants themselves before him, carefully consulting their characters at each successive step.

It is also assumed that the student possesses the requisite knowledge of vegetable structure, such as may be collected from the preceding chapters of this treatise, or from any similar elementary work; without which knowledge neither certainty nor satisfaction is attainable in the study of plants. The student is likewise supposed to be provided with a *Flora*, or systematic work containing botanical descriptions of plants, arranged according to the natural method; either a general system comprising all known species, or, which is more convenient, a local Flora embracing the plants of the particular district or country in which he may reside.* In works of this kind, all the genera and species of the district they embrace are described and arranged under the proper orders and classes.

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* The only universal Flora arranged according to this method, which has as yet advanced to any considerable extent, is the *Prodromus Systematis Naturalis Regni Vegetabilis* of De Candolle. Four volumes of this work have been published, comprehending all the families (100 in number) up to Compositæ; and a fifth, comprising that large order, is now daily expected. We may obtain some idea of the formidable extent of a general Flora at this day, and of the immense and rapid increase in the number of known plants, from a recent statement of De Candolle, viz: that the number of species in the single family Compositæ now in his possession, considerably exceeds the whole vegetable kingdom as known to Linnæus. The earliest attempt at arranging North American plants in natural orders, was made in 1815 by the late Abbe Correa, who published anonymously, and in a pamphlet form, a list of the genera contained in the Catalogue of Muhlenberg, arranged according to the natural families of Jussieu. The first treatise in this country describing any considerable number of plants in which the natural method is adopted, is the elaborate *Account of the plants collected by Dr. James, in a journey to and from the Rocky Mountains*, by Professor Torrey. This Florula, as it may be called, was published in 1827, in the second volume of the Annals of the Lyceum of Natural History, New-York. We have as yet no Flora of North America, arranged according to the natural method; and the last general work describing the plants of this country is that of Pursh, published in the year 1814. A new Flora, adapted to the present state of science, and embodying the numerous discoveries of the last twenty years, is therefore greatly needed at the present time. It is, perhaps, generally known to the cultivators of botany in this country, that Professor Torrey, who has so long and so successfully labored in North American botany, and in accumulating the materials for the purpose, is now

209. Let us suppose the student, thus prepared, to have before him specimens of the common *American Columbine* (found on rocks, in early spring, throughout the whole extent of the United States), which he proposes to identify by means of the natural method.

The first step in the investigation is to determine whether the plant under consideration belongs to the first or second class—to Flowering or Flowerless plants. The presence of flowers, consisting of floral envelopes, stamens, and pistils, clearly proves that it belongs to the first class. Or, if specimens in fruit be examined, the same conclusion is reached by observing regular seeds, enclosed in a seed-vessel and attached to a placenta, as in all Flowering plants.

Flowering plants are found to comprehend two great groups or sub-classes, distinguished by their different modes of growth, and also by the structure of the stem, leaves, and embryo of the seed, viz: 1st, Exogenous or Dicotyledonous plants; and 2d, Endogenous or Monocotyledonous plants; the student accordingly proceeds to inquire to which of these the unknown plant belongs. The determination of this point, although appearing to require a recondite investigation, is in fact abundantly easy; and a just conclusion may be arrived at in several different ways. The student will, perhaps, first direct his attention to the stem, with the view of ascertaining whether it present the Exogenous or the Endogenous structure. In woody stems, or wherever the growth continues for more than one season, a bare inspection of a slice of the trunk suffices to determine the question. The distinction, however, is not obvious in herbaceous stems, such as the present instance; yet the presence of pith

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engaged in this formidable undertaking. The work is in such a state of forwardness, that the first volume may be expected to appear early in the ensuing year.

It is very desirable that the natural method should hereafter be adopted in our local Floras, a class of works extremely useful to botanical students. Dr. Beck's *Flora of the Northern and Middle States*, is, however, the only work of the kind, in which this method is adopted.

(unless it be destroyed by the rapid increase of the stem in diameter, thus becoming hollow), and of a separable bark, as also the conical shape of the stem, unequivocally indicate the Exogenous structure. Being aware that all the plants of this division exhibit dicotyledonous embryos, the student naturally proceeds to test the correctness of his view by dissecting the seed. Unless expert, however, in this kind of investigation, the student will not effect his object in this case, on account of the minuteness of the embryo; neither is it of any great practical consequence that he should do so, since the end may be attained much more readily, and with nearly the same certainty, by other means. "In natural history," as Professor Lindley justly observes, "many facts have been originally discovered by minute and painful research, which, when once ascertained, are readily to be detected by some more simple process, of which Botany is perhaps the most striking proof that can be adduced." Accordingly, in instances like the present the student finds it unnecessary to dissect the seed for the purpose of deciding to which grand division the plant belongs, since it is known that the structure of that organ corresponds with a peculiar structure of the stem, leaves, and flowers, the most conspicuous organs of the plant. The student therefore directs his attention to the leaves, and observes the mode of veining, having learned that the branching of the veins in a reticulated manner indicates the Exogenous, and the parallel-veined arrangement, the Endogenous structure. The leaves in the plant under consideration manifestly exhibit the reticulated mode of veining, the ramifications of the veins uniting with each other so as to form a fine net-work over the whole surface. The plant, therefore, clearly belongs to the first sub-class, viz: the Exogenæ or Dicotyledones.

The next step, which is generally the most difficult of all to the beginner, is to refer the plant to the proper order or natural family. The labor of the student is, however, considerably diminished by the more or less artificial arrangement of the orders, as already specified.

If the work he is consulting adopt the subdivisions proposed by De Candolle, the student finds all the Exogenous families grouped in four sections, viz: the Thalamifloræ, the Calycifloræ, the Corollifloræ, and the Monochlamydeæ; and he is accordingly required to decide to which of these his plant belongs.

The first section (Thalamifloræ) is characterized by having a calyx of several sepals, and (usually) a corolla of several distinct petals, which, when present, arise directly from the receptacle, and do not adhere to the calyx. The stamens are also hypogynous, arising from the common base of the flower, and being wholly unconnected with the calyx.

On examining the plant before him in reference to these particulars, the student observes two rows of floral envelopes; the outer consisting of 5 oblong scarlet-colored leaflets; and the inner of 5 bodies alternate with the former, and somewhat resembling them, except in being drawn out at the base into long tails or spurs: the outer series is accordingly recognized as the calyx, and the inner as the corolla (109). The 5 petals are moreover observed to be distinct, and free from the sepals; the numerous stamens, also, arise from the receptacle at the base of the ovaries, and are unconnected with the calyx; *i. e.* they are, in botanical language, *hypogynous.* It is therefore evident that the plant belongs to the section *Thalamifloræ;* and the student may confine his attention to the orders of that division. He accordingly proceeds to examine the essential characters, or condensed descriptions of the several orders, carefully comparing the characteristics of each with the plant under consideration, until an order is found with the characters of which the plant agrees in every essential particular.

The family Ranunculaceæ (the *Crow-foot tribe*) is commonly placed first. This tribe, the student finds to be characterized by having a calyx of several, usually 5, distinct sepals, and either the same number of petals, or twice or three times that number; although the latter are occasionally wanting: the flowers of the unknown plant uniformly present 5 sepals and 5 petals, all distinct and unconnected. The stamens in the Crow-foot tribe are distinct and numerous; with adnate anthers, opening on the outer side: the student turning to the flowers under examination, perceives them to exhibit 20 or more stamens, provided with anthers which are attached to the outside of the summit of the filaments, and accordingly corresponding in these particulars with the characters of the Crow-foot tribe. The pistils in that family are usually several in number, and *apocarpous:* the plant under consideration is seen to have 5 unconnected pistils.

The flowers of the plant having thus been found to agree with the Crow-foot tribe, the student proceeds to examine the fruit, which in that tribe consists either of one-seeded achenia, or of several-seeded follicles: the mature carpels of this plant are found to be dehiscent by the inner suture, along both edges of which several seeds are borne; they are, therefore, follicles. The student next examines the seeds themselves, and on cutting them across, observes that their principal bulk consists of a firm albumen, having nearly the texture of horn when the seed is fully ripe. With the aid of a microscope he will perhaps discover the minute embryo, lying in the midst of the albumen close by the hilum of the seed. In all these respects the plant coincides with the characters of the Crow-foot tribe, and the student, therefore, confidently refers it to that order.

The Ranunculaceæ have herbaceous or climbing stems, which contain an acrid or poisonous watery juice, never milky as in a nearly related tribe. The leaves are alternate, often variously lobed or divided, and the petioles are dilated at the base, so as partly to clasp the stem: all these peculiarities are presented by the plant under consideration.

The family being thus ascertained, the chief difficulties in the way of attaining a knowledge of the plant are surmounted; since the characters of the genera are abundantly simple and easy. Much useful knowledge is already attained, even if the investigation should not be carried further: the student has learned that not only this, but all plants of the family, are unfit for the food of men or animals; the juice being always more or less noxious, and in several cases extremely caustic and virulent; whereas if the student had employed the artificial system, although the class and order would have been easily ascertained, the difficulties would not be in the least diminished by the preceding steps; and if compelled to stop at this point, he will not have attained the smallest portion of available knowledge.

Proceeding with the investigation, the student finds that his plant belongs to the Hellebore section of Ranunculaceæ, the plants of which are distinguished from others of the family, by having colored and petal-like sepals, tubular, spurred, or otherwise irregular petals, and follicular fruit. This group comprises several genera, all more or less resembling the plant under consideration; such as Aconitum, which contains the Monk's-hood, Delphinium, including the Larkspurs, Nigella, the Fennel-flower, &c. The student, however, finds the plant under examination to differ from all those genera in the form of the calyx and corolla; but to agree in every respect with the characters of a remaining genus, viz. AQUILEGIA.

This genus comprises several species of Columbine; and the student therefore proceeds to compare the leaves, flowers, &c. of his plant with the characteristic description of each species, and thus ascertains it to be *Aquilegia Canadensis*, the common wild Columbine of North America.

This method of investigation may appear tedious; and in the case of a beginner it necessarily occupies considerable time; but when correctly prosecuted, each step renders the succeeding ones easier, and the proposed result is attained with certainty. The operation, also, is facilitated by each attempt; and when a single plant of an order has once been studied in this way, the student has necessarily acquired such an amount of knowledge respecting the whole order, that he rarely meets with any formidable difficulty in the examination of other plants of the same family.

210. We will suppose the *Blood-root* to be the next subject for examination, and that the student is provided with specimens both in flower and in fruit, the latter being always desirable, whether the artificial or natural system be adopted.

The student first enquires, as before, whether the plant belongs to the Flowering or Flowerless class: the presence of flowers or fruit decides this question at once in favor of Flowering plants. He next enquires whether it belongs to the sub-class Exogenæ or Endogenæ: passing by other characters, the student examines the structure of the leaves, as affording the most convenient means of arriving at this knowledge, and observing the branched and reticulated arrangement of the veins, he confidently refers the plant to the first sub-class, viz: Exogenæ.

The next step in the investigation is to determine the section, or group of orders, to which the plant belongs; and for this purpose the flower is submitted to examination. The student observes a single pistil, occupying the centre of the flower, surrounded by 24 stamens; and, recollecting that the position or *insertion* of the stamens affords one of the chief distinctions of the sections, he remarks that in this, as in the preceding instance, these organs grow out of the receptacle at the very base of the pistil, and are not in any way coherent with the floral envelopes; they are, accordingly, in botanical language, *hypogynous.* The student also observes a row of white, regular-shaped, unconnected petals, commonly 8, but in some flowers 12 in number; and remarks that these are also *hypogynous*, having the same insertion as the stamens. He may at first be puzzled to decide whether the floral envelopes consist of a corolla, or a colored calyx; having learned that no dependence can be placed upon color as an index, and that when only a single whorl exists it is considered to be a calyx, whatever be its color or texture (109). The examination of an unexpanded flower obviates this difficulty, the student perceiving the corolla to be enclosed by a delicate calyx of two pieces, which drop off when the flower expands.

After this examination, it is plain that the plant belongs to the section *Thalamifloræ*, distinguished by having hypogynous stamens and hypogynous unconnected petals.

Having thus ascertained the plant to appertain to the same section with the one first examined, the student may next compare the two plants with each other, for the purpose of obtaining a clear idea of the points of difference. They mutually agree, as already remarked, in presenting the Exogenous structure, and in having numerous distinct, hypogynous stamens, and several uncombined hypogynous petals. The Columbine, however, was found to exhibit 5 sepals and 5 petals, the former being the most permanent, and often remaining a short time after the petals have fallen ; whereas, in the present plant, there are only two very fugacious (*caducous*) sepals, and either 8 or 12 petals. The student next compares the stamens of the two plants, and although they are about equally numerous, yet several differences are observed. Thus, those of the Columbine are commonly about 20 in number; whereas those of the present plant are invariably 24: in the first the anthers are *adnate*, or attached to the filaments by one side; in the second the anthers are *erect*, or fixed by one end to the very summit of the filament. The attention of the student is next directed to the pistils, with the view of ascertaining whether the solitary pistil of the plant under examination be really simple, or formed of a single carpel; or whether it be composed of two or more carpels in a state of cohesion. This is a point of no small consequence, since *apocarpous* and *syncarpous* pistils are seldom found in the same family. In this case, the ovary is found to present two opposite grooves, indicating either the two sutures of a simple carpel, or the junction of two combined carpels. The presence of two stigmas proves the latter view to be the correct one; and this is confirmed, on cutting open the ovary, by finding the seeds to be attached along both these lines. Inasmuch as a simple pistil has the seeds attached to the inner or ventral suture solely, the ovary in the present instance is manifestly *syncarpous*, and composed of two carpels, with the seeds attached to parietal placentæ. The plant under consideration is accordingly found to differ from the Columbine, and the whole family to which the latter belongs, in having syncarpous instead of apocarpous ovaries. The student has also remarked a constant difference in the relative number of the parts of the flower; the Columbine exhibiting the quinary arrangement, viz: 5 sepals, 5 petals, about 20 stamens (or 4 whorls), and 5 pistils; whereas the present plant has 2 sepals, 8 petals (usually), 24 stamens, and 2 combined pistils, thus exhibiting a quaternary arrangement.

The student now proceeds to examine the ripened ovary, which presents the appearance of an elongated capsule, containing numerous seeds. The seeds are so large that a raphe is plainly observable without the aid of a microscope, like a worm lying along one side of the seed (*fig*. 109, *i*.), which is thus known to belong to the anatropous form. On cutting open the seeds, the student observes a copious albumen, which, instead of having a horny texture as in the former example, is somewhat granular and filled with oil.

This plant is also remarkable for abounding in a red, or deep orange milky juice, from which its popular name is derived; whereas the Columbine and all similar plants are provided with a watery juice.

The student may contrast the chief characters of the present plant with those of a former example, in the following manner:

The Columbine has,	The Bloodroot has,
A *quinary* arrangement of the floral organs.	A *quaternary* arrangement of the floral organs.
Sepals falling with or after the petals.	*Sepals* falling when the flower expands.
Anthers adnate, opening outwardly.	*Anthers* erect, opening along each side.
Ovaries apocarpous.	*Ovaries* syncarpous.
Seeds with a horny albumen.	*Seeds* with an oily albumen.
Stems with an acrid watery juice.	*Stems* with a milky (red) juice.

From this synoptical view, it will be at once perceived that these two plants cannot belong to the same family, although resembling each other in some respects; and that the Blood-root, consequently, does not belong to the Crow-foot tribe. The student accordingly proceeds to compare the essential characters of the plant with the description of the several orders immediately succeeding the Ranunculaceæ; and thus he readily discovers it to belong to the *Papaveraceæ* or Poppy tribe; an order nearly related to the former in many respects, as the student at once perceives; but distinguished chiefly by the caducous sepals, the syncarpous ovaries, the seeds with oily albumen, and the milky juice; the identical characters in which the present plant essentially differs from the preceding. If the student examine the common Poppy, the Prickly Poppy (*Argemone*), and the Celandine (*Chelidonium*), plants of very common occurrence, he will find that they all have the above-mentioned characters in common; and accordingly they, with the Blood-root and a few other kinds, compose a single family, called Papaveraceæ, or the Poppy tribe, being named from the most familiar plant of the order. These are all furnished with milky juice, which is white in the Poppy and most others, although orange in the Celandine, and orange-red in the Blood-root, yet it is in all of a narcotic or stupifying nature; not acrid and blistering as in the Crow-foot tribe. The compound pistil in the true Poppies consists of from four to twenty, and in the Prickly Poppy of from four to seven carpels or simple pistils, cohering so as to form a single body. The Celandine and several other plants of the family, however, have a pod formed by the union of two carpels. as in the present plant; yet the number of petals, stamens, &c., distinguish the latter from those arranged next to it, so that the student at once recognizes our plant as belonging to the genus SANGUINARIA. Only one species being known of this genus, viz: *S. Canadensis*, no specific character is given, the only object of which is to distinguish from each other the several species of a genus.

211. It is a common opinion that the principles of the natural system, however useful to the skilful botanist, are too difficult to be practically applied by the uninitiated student. It is true that difficulties are to be

encountered, although they have, we believe, been very much overrated; yet these difficulties exist in the science itself, and are not attributable to the system, since *they are inseparable from the acquisition of knowledge by means of any classification whatever.* They must accordingly be met and overcome; and the method now proposed is the most direct, the most natural, and by far the easiest way of overcoming them. By pursuing some other course the name of an unknown plant may, perhaps, be ascertained *in a single instance* with less trouble; but the difficulties, though evaded, are not at all diminished, since the same extent of investigation must necessarily be gone through before the same amount of knowledge can be attained. When the student has surmounted these obstacles, and has accurately studied any single plant of a family, he afterwards proceeds with confidence and certainty, scarcely ever meeting with any difficulty whatever, so far as that order is concerned; and, moreover, each successful investigation of the kind greatly facilitates every subsequent attempt. In an artificial method, on the contrary, the same kind of difficulties have to be settled in every individual instance, while the determination of one genus throws no necessary light upon kindred genera, and consequently the progress of the student is slow and uncertain. We have, therefore, no hesitation in affirming that the science of botany, instead of becoming more and more difficult, as some persons suppose, is really of easier acquisition than at any former period, notwithstanding the immense increase in the number of known plants during the last few years.

Since the most formidable obstacles experienced by a beginner in the application of the natural method, arise from the difficulty of discriminating the essential characters of the orders—a difficulty only to be overcome by practice—it may not be amiss to adduce several additional examples from different families; which, while they indicate the proper method of surmounting these obstacles, may also show that they present no serious barrier to the progress of the student. We select for this purpose a few species of ordinary occurrence, and beg the student to follow out the investigation in detail with specimens of the plants themselves before him.

Let us take, in the first place, one of the handsomest of our vernal plants, commonly known by the name of *Wild Pink*. The first enquiry is, does the plant bear flowers and produce seeds? This being answered in the affirmative, it is known to belong to the first class or grand division—that of Flowering plants. The question next arises: Is the plant Exogenous or Endogenous? The reticulated veining of the leaves at once decides this point, independently of a central pith, a separable bark, and the quinary arrangement of the flower. We next ask, has it distinct and hypogynous petals and stamens? This being found to be the case, we know that the plant belongs to the section *Thalamifloræ*. Having with the greatest ease attained to this point, we are now prepared to notice the chief peculiarities of the principal organs of the plant. We observe that the stem is tumid at the joints or nodes; that the leaves are *opposite*, with the margins *entire* or uncut; that the flowers consist of 5 sepals united for a great part of their length, 5 petals with long claws, and a spreading lamina, forming what is called a *caryophyllaceous* corolla (as in *fig.* 72, *a.*), 10 regular, unconnected stamens, and a single ovary surmounted with 3 styles. If we cut open the ovary by a transverse incision near the top, it is observed to be one-celled, although consisting of three portions, and the seeds are borne on a central columnar placenta, apparently free from all connection with the sides of the ovary. If, however, this organ be divided near the base, we observe three delicate partitions, stretching across from the walls or valves to the spongy central body which bears the seeds; and thus the nature of this anomalous structure is manifest, as elsewhere explained.* It will be seen that the styles do not bear stigmas on their summits, as is commonly the case, but the whole inner surface of each style is stigmatic.

We next examine the mature ovary, and find that it has become a dry capsule, opening, when fully ripe, at the summit by six short teeth. If we proceed to examine the seeds, a small microscope will be required, by the aid of which we observe that they are kidney-shaped, and thickly beset with elevated dots arranged in regular lines, both extremities of which meet in the vicinity of the hilum, just as in *fig*. 109, *c*. We may divide a seed with a sharp knife, when, if our microscope be sufficiently powerful, we shall observe the same appearance as that represented in *fig*. 110, *d*., viz: a curved embryo lying in the midst of mealy albumen, both extremities being approximated to the hilum. The seeds of our plant are thus proved to be *campulitropous*, or curved, although this might be safely inferred from the shape and external marking without dissection.

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* See page 198, and *fig.* 80. *d.*

It should here be remarked, that although the examination of the seed is desirable, and is by no means difficult, yet it may be wholly dispensed with by the young beginner, since the family of the plant may be satisfactorily ascertained without this investigation.

Let us now exhibit in one view the chief particulars in which the plant under consideration differs from those previously examined, passing over those of minor importance. The principal peculiarities of our plant are:

1. The *swollen joints* of the stem.
2. The *opposite* leaves.
3. A *syncarpous* ovary, while the styles are distinct.
4. The styles being stigmatic on the inner side throughout their whole length.
5. A one-celled capsule, opening by teeth at the summit.
6. A *free central placenta.*
7. *Campulitropous* seeds with mealy albumen.

From this view, it is abundantly manifest that our plant belongs to a distinct order from either of the preceding, as its different habit also denotes; and by examining the characters of the remaining families of the Thalamifloræ section, we find that the peculiarities just enumerated are exactly those which distinguish the

Caryophyllaceæ or Pink tribe, and no other. We have thus arrived at the knowledge of a third tribe, so well marked that the student will hereafter scarcely fail to recognize, almost at first glance, all the other plants it contains. This family is usually divided into two sections; the one, characterized by having distinct sepals, includes the Chickweeds and Sandworts; the other has the sepals united into a tube, and the petals furnished with long claws, and comprises the true Pinks, the Campions and Catchfly, the Cockle, the Soapwort, &c. Our plant evidently belongs to the latter group. The genera are distinguished by very simple and easy marks. Thus, the true Pinks and the Soap-wort have 2 styles, the Cockle has 5 styles, and the genus *Silene* has 3 styles, the petals being moreover crowned with an appendage at the summit of the claw: to the latter, therefore, our plant evidently belongs.

This genus (SILENE) comprises a large number of species, and we accordingly proceed in the usual way, comparing our plant with the description of each, and thus easily arrive at its specific name, viz: *S. Pennsylvanica.* Thus closes the investigation, and the student finds that he has not only ascertained the name of the plant in the most certain manner, but has likewise attained to a knowledge of the structure and general appearance of a very interesting tribe.

We select the Strawberry as the next example, which may serve to illustrate a very important family. The flowers and leaves immediately show it to be an Exogenous plant; and we therefore at once proceed to ascertain the section to which it belongs. In general habit the plant has a resemblance to several of the Crow-foot tribe, but we notice a peculiarity not observed in the former examples, viz: both the petals and the stamens seem to grow out of the calyx instead of beneath the ovaries. They are, therefore, in botanical language, *perigynous;* and we thus arrive at the conclusion that the Strawberry belongs to the section *Calycifloræ.* We are now prepared to search for the order to which this plant is referred; and accordingly endeavor in the first place to attain a general knowledge of its structure. The calyx of the Strawberry is composed of 5 sepals, united for a part of their length, and 5 smaller leaflets forming an outer row adherent to the first; the latter may be viewed either as an outer calyx or a series of bracts. The corolla consists of 5 petals, growing out of the side of the calyx, as already observed. The stamens are exceedingly numerous, and are placed in a crowded ring around, but not beneath, the pistils. The pistils are also numerous, and crowded together in several rows upon an enlarged central receptacle. Each pistil consists of a small one-seeded ovary, furnished with a short lateral style, which is terminated by a minute stigma. We have elsewhere adverted to the changes which the pistils of the Strawberry undergo in becoming fruit (143, 152, 164). The receptacle, covered with the numerous carpels, is at first much smaller than the calyx, being enclosed by the latter after the petals and stamens have fallen. The fleshy receptacle soon begins to swell, and to become soft and juicy; its growth continuing until it much exceeds the calyx in size, and the minute carpels scattered over its surface, having now lost their styles, greatly resemble seeds, for which they are usually mistaken. They are, however, true fruits (*achenia*), containing a single seed, which may be detected on cutting open the carpels. The Strawberry is, therefore, an *aggregate fruit* (164), and very different from a real berry.

On cutting open a seed, the embryo is seen to occupy the whole cavity, and there is no appearance of albumen. If the student is not provided with a microscope, he may examine the seed of the apple instead of the Strawberry (both having precisely the same structure) where the several parts of the embryo are plainly distinguishable to the unassisted eye, the radicle lying next the hilum, and the two cotyledons occupying the chief bulk of the seed.

The foliage of the Strawberry exhibits no striking peculiarity, except in the presence of stipules, which are wanting in all the plants previously examined. These in the case before us are membranous, and coherent with the base of the leaf-stalk, one on each side. The leaves are alternate.

If the student examine the characters of the several orders of the section *Calyciforæ*, he will meet with only a single tribe which exhibits the essential characters presented by the Strawberry, viz: *apocarpous* ovaries, either one or two seeds destitute of albumen, numerous perigynous stamens, a regular calyx and corolla, and alternate leaves, furnished with stipules. These characters distinguish the *Rosaceæ*, or Rose tribe. Having ascertained the family, the student finds no difficulty in referring the plant to the proper genus and species. He also learns that all the plants of the order are wholesome (except that the leaves and seeds of several contain prussic acid), the fruit always innocent, and often used for food. He may therefore partake, without hesitation, of the fruit of any unknown plant presenting the characters just mentioned. The study of this plant has, moreover, enabled the student to understand the numerous allied plants; such as the Barren Strawberry, Cinquefoils (*Potentilla*), which essentially differ from the Strawberry in having a hard and dry, instead of a swollen and pulpy receptacle, and the Avens (*Geum*), which differ from Cinquefoils only in the styles remaining on the carpels and becoming long tails. The Raspberry and Blackberry (*Rubus*) are also recognized as members of the same tribe, botanically differing from the Strawberry chiefly in the carpels becoming juicy, while the receptacle remains dry. The receptacle is convex in all these examples, but the Rose exhibits another modification of a highly interesting nature, as viewed in connexion with the plant just examined. In that genus the receptacle is hollow, forming a complete thin lining to the urn-shaped tube of the calyx (*fig.* 81, *a*, *c*), and the numerous one-seeded ovaries are attached to the whole concave surface. The student accordingly perceives that the structure of the Rose is essentially the same as that of the Strawberry, Raspberry, &c., and that it merely forms another genus of the same tribe.

From this point the student may advantageously extend his enquiries to the Apple and Pear, the flowers o which are in no way different from other Rosaceou plants, except in having much fewer styles. In these however, the ovaries are perfectly enclosed by th thickened calyx, so as to be called in botanical language *inferior*, and also slightly cohere with each other in the centre, forming a kind of *syncarpous* fruit Each carpel contains one or two seeds, like those of the Rose tribe, except that when two are present they stand side by side, and not one above the other. On accoun of these differences the Apple, Pear, &c., are considered to form a separate group, called Pomaceæ, differing, however, too little from the Rose tribe proper to constitute more than a sub-order.

The student should next examine the Cherry, Plum, and Peach, in which he will recognize a group of plants nearly allied to the Rosaceæ. The flowers are similar to those of the Rose tribe, except that there is a solitary (superior) pistil, which in fruit becomes a *drupe*. These plants accordingly seem to form another section of the same order, the difference in the fruit not being of itself sufficient to separate them ; but they at the same time exhibit an important peculiarity in their sensible qualities. Instead of being perfectly wholesome, the bark, leaves, and seeds of all those plants contain a quantity of prussic acid, which is well known in a concentrated state to be one of the most violent poisons. Although the odor of this substance is perceptible in the whole group, yet it does not exist in sufficient quantity to produce deleterious effects, except in the Cherry-laurel (*Prunus Lauro-Cerasus*), and the Evergreen Cherry of the Southern States (*P. Caroliniana*), the leaves of which are very poisonous, and, as observed by Elliott, " frequently in the spring of the year destroy cattle that are tempted to browse freely on them." On this account these plants are sometimes considered to form a separate family, under the name of the *Amygdaleæ*, or Peach tribe.

Did our limits allow, we might profitably introduce a great number of examples, illustrating the method to be pursued by the student, and showing at the same time how the study of a single plant leads directly to a knowledge of the structure and properties of a whole tribe. Since, however, we can only adduce a single additional instance, we choose a plant of very different structure from those heretofore considered, viz: the Common Iris, or Blue Flag.

The plants already examined, although belonging to several different families, all agree in having branching stems, leaves with reticulated veins, jointed with the stem so that they are thrown off at certain seasons, and flowers with the parts in fours or fives; by which characters they are known to belong to the Exogenous or Dicotyledonous division, even without dissecting the seed or examining the structure of the stem.

The plant now considered is differently constituted in these respects; the leaves being parallel-veined, clasping the stem at the base, and never separating by an articulation, but decaying when old on the stem; the parts of the flower, moreover, exhibit the ternary arrangement. It is therefore clear, without further investigation, that the plant is Endogenous; the order is accordingly to be sought after in the second sub-class of Flowering plants, viz: the *Endogenæ* or *Monocotyledones*.

The Endogens are sometimes divided into such as are furnished with a calyx or corolla (*Petaloideæ*), and those destitute of a proper perianth, but furnished with glumes, &c. (*Glumaceæ*). The Iris is of course referred to the first of these divisions, which some authors subdivide into three sections, viz: those with *hypogynous* stamens, those with *perigynous* stamens, and those with *epigynous* stamens. In our plant, the tubular perianth appears to grow out of the summit of the ovary; the latter is consequently inferior; and the three stamens, concealed by the broad petal-like stigmas so as almost to escape our notice, have the same origin. The plant, therefore, belongs to the last-named subdivision. By examining the several families brought together by the character of epigynous stamens, we shall experience little difficulty in ascertaining that to which our plant belongs. The Orchis tribe is known from all others by a peculiar irregular perianth, *gynandrous* stamens, and parietal placentæ,—a structure wholly different from our plant, which presents a nearly regular perianth, distinct and unconnected stamens, and placentæ in the axis of the ovary. The Ginger tribe (*Scitamineæ*) and the Arrow-root tribe (*Marantaceæ*) are excluded by having solitary stamens and a one-seeded fruit, to say nothing of other characters; whereas our plant has three perfect stamens, and a three-celled, many-seeded ovary. On examining the stamens of the plant under consideration, we observe the long anthers to be attached by their entire length to the outside of the filaments, and accordingly to *face outwardly*, or *from the style*. They are seen to open in the usual manner by two parallel lines throughout their whole length, and are observed to be placed opposite the outer segments of the perianth (*i. e.* the sepals). Now the Dioscorineæ, the Hypoxideæ, the Hæmodoraceæ, and Amaryllideæ (the latter agreeing with our plant in many points) have, for the most part, six stamens, all facing *inwardly*, or *toward the styles*. The Iris can, therefore, belong to none of these families. A remaining small order, the Burmannieæ, agrees in several respects with our plant, and in the number of the stamens; but these are situated opposite the inner segments of the perianth (*corolla*), and, moreover, the anthers open by a transverse line. By thus following a negative analytic method, we have excluded all the Endogenous families of any consequence, save one, viz: the *Irideæ;* and if the characters of that tribe are exhibited by the plant under consideration, we shall have attained our object. We find this to be the case, the Iris tribe being essentially distinguished from kindred families by a tubular, six-parted perianth, three stamens, with the anthers turned outwards and opening longitudinally, an inferior, three-celled ovary, dilated stigmas, and a many-seeded capsule, with loculicidal dehiscence; all of which characters are presented by our plant. The leaves in that tribe are described as two-ranked and equitant, or erect; and the flowers are provided with spathaceous bracts. These peculiarities are also observed in our plant, rendering it, therefore, certain, from positive as well as negative analysis, that it belongs to the Iris tribe. The investigation need not be further pursued, since, after the order is found, the determination of the genus and species is effected in the usual way.

The mode we have indicated in our last examination may be at all times advantageously adopted by the student; since by first rejecting, by means of a few obvious characters, a great part of the orders comprised in the section, the task of discriminating between the few remaining families is rendered comparatively easy.

212. If these cursory illustrations have succeeded in showing the ready applicability of the natural method to the study of plants, we have effected our object, since even those who are not convinced of its practicability readily admit the many and great advantages derivable from its adoption. Some, however, who allow that the study of natural affinities forms the true ultimate object of botanical science; yet nevertheless conceive it neither practicable, nor indeed desirable, to inculcate these principles upon the young student, whom they recommend in the first place to study plants by means of the artificial system of Linnæus, as forming, in their opinion, a proper introduction to the natural method, which may be wholly adopted when the student shall have attained to a sufficient degree of advancement.

If the artificial system were in its nature introductory to the study of natural affinities, then, indeed, its alleged simplicity of application might render this course advisable: but inasmuch as the ulterior object of the student is in no wise promoted by such preparatory study, it will be at once seen that much time is wasted in acquiring mere technical learning to be eventually abandoned, while the real knowledge incidentally gained in his progress might be acquired much more easily, satisfactorily, and expeditiously, had the study of the natural method been commenced in the first instance. We contend, moreover, that, so far from facilitating his future progress, the student is in fact retarded by commencing with the study of the artificial system; since he is thereby insensibly led to associate in his mind plants having no natural alliance, and falsely to estimate the value of characters.

The great number of families of which the vegetable kingdom is composed, induces some persons to imagine that the study of plants upon the natural system cannot be advantageously prosecuted without an acquaintance with a very large number of vegetable forms. It is true that between two and three hundred different orders are now admitted in our methodical arrangements, and it is equally true that a general acquaintance with the diversities of structure they exhibit is necessarily attained by the erudite systematic botanist. The catalogue of natural orders subjoined to this work will, however, show the student that such extensive acquirements are by no means requisite for satisfactorily studying, and even for making extensive progress in the botany of this or any other country. Although about two-thirds of the known orders have representatives in North America, yet the principal part of our vegetation is comprised within a very moderate number of families. No less than thirteen sixteenths of all the Flowering plants of North America, so far as at present determined, belong to 35 orders; and nine orders comprise about half of the whole number! It is therefore manifest that an acquaintance with a few important and well-known tribes, such as the Compositæ, the Grasses and Sedges, the Pea tribe, the Cruciferæ, the Rose tribe, the Umbelliferæ, the Pink tribe, &c., offers the key to the knowledge of nearly all our plants. The student will more fully apprehend the facilities afforded by the natural method, when he is reminded that a careful and thorough study of even a single plant in the principal divisions of each order leads directly and certainly to a general knowledge of the structure, habit, uses, and sensible properties of the whole.

SECT. IV. *Of Botanical Nomenclature.*

213. The earliest botanical writers usually adopted the names by which the plants they described were known in Greece and Italy; but the great increase in the number of plants entirely unknown to the ancients soon rendered this plan wholly insufficient. Each species was at first designated by an independent name; and thus many of our generic names originated, such as *Platanus*, under which the Plane-tree is mentioned by Dioscorides, and *Lactuca*, employed by Pliny to designate the Lettuce.

The continual discovery of new plants, however, at length rendered this method impracticable, on account of the prodigious number of names required to give each plant a distinct epithet; and, moreover, it offers no way of expressing the mutual alliances of plants. Accordingly, when a new plant was discovered resembling some well-known species, it was called another kind, or a second genus of such plant; and sometimes the points of difference were expressed by the name applied to the new plant: in this way arose such names as *Geranium minus*, *Anagallis cæruleo flore*, &c. As the number of species increased, these names were necessarily made longer, so as to comprise the distinguishing marks of each species. Thus, in designating the several species of Ranunculus, the common Crow-foot was termed *Ranunculus pratensis erectus acris*; another species (R. sceleratus) was named *R. secunda species*; a third (R. repens) was called *R. repens flore luteo simplici*; and a fourth (R. abortivus) *R. foliis radicalibus reniformibus crenatis petiolatis, caulinis paucis digitatis sessilibus.* The more the number of species increased, the longer did these names become; in some instances consisting of as many as 15 or 20 words. Thus, a species of Monarda was known by the name of *Clinopodium angustifolium non ramosum, flore cæruleo: labio trifido atro purpureis maculis ornato.* These tedious phrases, which were necessarily repeated every time a known plant was designated in conversation or in writing, must have formed a serious obstacle to the progress of the science, until the adoption of the Linnæan nomenclature. Linnæus proposed that the name of every plant should consist of two words; one designating the genus, the other the species. The first is termed the generic name, and is always a substantive: the second is the specific name, and is usually an adjective.

Linnæus framed a system of rules respecting the application of these names, which are for the most part followed by all succeeding botanists. The most important of these are the following.

1. Generic and specific names must be of Greek or Latin derivation, and should always be written in Latin.—This rule, however, was occasionally departed from in the time of Linnæus, as well as by many succeeding writers. Thus *Thea* and *Coffæa*, both adopted by Linnæus, are formed by latinizing the barbarous names of these plants: and botanists now incline to introduce many instances of this kind, when the vernacular name is harmonious, and easily reconcilable with the Latin tongue. Thus we have *Nelumbium* from the popular name Nelumbo, *Bambusa* for the Bamboo, &c. Specific names are not unfrequently drawn from the same source.

2. No names compounded of both Greek and Latin, can be on any account admitted.

3. The best generic names are those that indicate some obvious peculiarity of the genus; either as to the situations in which it grows, as *Arenaria*, a plant that inhabits sandy places; or such as mark the botanical characters; as *Streptopus* of Michaux, applied to a plant the peduncles of which are bent in a remarkable manner; *Hemianthus* of Nuttall, applied to a plant whose corolla is apparently cleft or halved; and *Macranthera* of Torrey, to designate a genus distinguished by the remarkably long stamens.

4. Genera are sometimes dedicated to persons who have distinguished themselves in the science; thus *Muhlenbergia*, *Elliottia*, *Schweinitzia*, *Balduina*, *Nuttallia*, and *Darlingtonia*, commemorate several botanists

of our own country, Plants, however, should never be named after persons who have not in any way contributed to the advance of natural history; such honors are justly considered as the greatest that can be conferred upon a naturalist; "they are the only reward he can expect, and are intended for him alone."

5. Generic names previously employed in zoology, should not be employed in botany; hence *Cristatella* of Nuttall is objectionable. This rule, however, is little regarded at the present day.

6. A generic name nearly approaching that of any older genus in sound, should be avoided.

7. A few generic names have been formed by transposing the letters of a well-known allied genus. Ex. *Tellima* of Brown; an anagram on *Mitella;* but this practice is not commendable.

8. Specific names are formed on similar principles to those of genera; only that more latitude is allowed in many respects. They are commonly framed to express some distinguishing mark of a species, or some striking peculiarity in appearance, or to denote the station in which the plant naturally grows. *Viola palmata*, and *pubescens* are examples of the first kind, *V. blanda* and *debilis* of the second, and *V. palustris* of the third. Comparative appellations are often employed, either such as *Viola primulæfolia*, *Quercus olivæformis*, *Comptonia asplenifolia*, *&c.*, or to indicate a general resemblance, as *Hypericum ascyroides*, *Ascyrum hypericoides*, &c.

9. Many specific names are derived from the country the plant inhabits; indeed a large proportion of North American plants bear the names of Viginiana, Canadensis, and Americana. Such names, however, are not often appropriate. Thus, *Prunus Virginiana* abounds throughout the whole of North America; *P. Americana* has no stronger claim to its specific name than twenty other species; while *Agrostis Virginica* grows wild in every warm climate. Names of this kind should always commence with a capital letter.

10. Specific names, also, are often bestowed in honor of botanists; such names should always commence with a capital letter. When a species is named after its discoverer or describer, the name must be a substantive in the genitive singular; as *Macranthera LeContii*, *Viola Muhlenbergii*, &c. When, however, the name is given in compliment to a botanist, the adjective form is assumed; as *Habenaria Hookeriana*, *Œnothera Lindleyana*, *Rhynchospora Torreyana*, &c

11. Species are sometimes designated by substantive names, especially when such name has once been generically applied to the plant by older botanists. In such cases the specific name retains its own gender and termination, and must begin with a capital letter. Ex. *Tussilago Farfara*, *Ranunculus Flammula*, *Hypericum Sarothra*.

12. Very long and uncouth names are as far as possible to be avoided.

13. The names first published, whether of genera or species, are always to be adopted, even in preference to much better ones, unless the former are absolutely in contradiction to universally received rules. In framing new names, however, it is desirable that all the canons of Linnæus should be observed.

14. Varieties are usually indicated by the letters of the Greek alphabet; when quite constant and distinct they also receive names similar to those of species. Ex. *Viola pubescens β. eriocarpa.* Names, however, should not be bestowed upon varieties except their characters are nearly as constant as those of the species.

15. Names of orders sometimes express the general or characteristic features of a tribe; as *Umbelliferæ*, *Cruciferæ*, *Leguminosæ*. More commonly, however, some genus is selected as the type of the family, and the name derived from it; as *Rosaceæ* for the Rose tribe; *Violaceæ* for the Violet tribe, &c. The name of the genus thus adopted is made into an adjective, and its termination prolonged into *aceæ* or *ineæ:* as Malva, *Malvaceæ*, Acer, *Acerineæ*. Sub-orders, and

sections of families are designated by changing the name of the principal genus of the group into an adjective without prolongation, being thus distinguished from those of orders. Ex. *Rosa*, Sub-order *Roseæ*, Order *Rosaceæ*.—*Ranunculus*, *Ranunculeæ*, *Ranunculaceæ*. Many names, however, are allowed to stand, although not in precise accordance with these rules.

CHAPTER VII.

GLOSSOLOGY.

214. In all the Natural Sciences it is necessary to express, with the greatest possible brevity and precision, a large number of ideas wholly unknown without the domain of these sciences, and altogether beyond the resources of ordinary language. In order that accuracy and uniformity may be attained in describing natural objects, and that the language of scientific writers may be exactly comprehended, all technical terms should be formed in accordance with general principles, and these, as well as all ordinary words employed in a restricted sense, should be fully explained in elementary works.

That branch of the science of Botany which furnishes definitions of the names applied to the different parts or organs of plants, and also to their various modifications, is called *Glossology.**

The names applied to organs are, of course, always substantives; consisting either of words in ordinary use, such as *leaf, flower, &c.*, or of words created by botanists, as *anther, pistil, pericarp,* &c. The epithets or terms employed to designate the diversities of figure, texture, arrangement, &c., which the different organs present, are adjectives. The former were, however, given when the organs were themselves considered; and at the same time we have also noticed the several terms applicable to each organ exclusively, and not to plants or their several parts generally. None of these will be repeated in the present chapter: in which we have only to define the characteristic terms used in botany without reference to any particular organ. We also omit all terms used in botany just as in their ordinary acceptation.

We employ the arrangement adopted by Prof. Lindley, considering it on the whole preferable to any we have hitherto met with. The following is a synoptical view of this arrangement.

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* Linnæus employed the word Terminology, which is objectionable because compounded of a Greek and a Latin word.

CHARACTERISTIC TERMS are either INDIVIDUAL or COLLECTIVE; the first applying to plants or their parts taken singly; the second to plants or their parts considered in masses.

CHARACTERISTIC INDIVIDUAL TERMS are either ABSOLUTE or RELATIVE.

CHARACTERISTIC INDIVIDUAL ABSOLUTE TERMS relate to;

1. *Figure.*
   A. with respect to general form.
   B. " outline.
   C. " the apex or point.
2. *Division.*
   A. with respect to the margin.
   B. " incision.
   C. " composition or ramification.
3. *Surface.*
   A. with respect to marking or evenness.
   B. " appendages.
   C. " polish.
4. *Texture.*
5. *Size.*
6. *Duration.*
7. *Color.*
8. *Variegation.*
9. *Veining.*

CHARACTERISTIC INDIVIDUAL RELATIVE TERMS COMPREHEND;

1. *Direction.*
2. *Insertion.*
   A. with respect to the mode of attachment.
   B. " situation.

CHARACTERISTIC COLLECTIVE TERMS RELATE TO;

1. *Arrangement.*
2. *Number.*

To the foregoing are added, 1st., *Terms of qualification*, consisting of syllables which, prefixed or annexed to a known term, modify or change its meaning; and, 2d., the *Signs*, or marks, used to express particular qualities or properties.

The mark (‖) which is prefixed to several terms in the ensuing enumeration, indicates that they are of uncommon occurrence in botanical writings.

I. OF INDIVIDUAL TERMS.

I. *Of Individual Absolute Terms.*

1. As to Figure.

A. *With respect to general form.*

Conical; having the figure of a cone, as the root of the Carrot (*fig.* 16.).

‖*Pyramidal*, or pyramid-shaped, is sometimes used in the same sense as conical.

Conoidal; approaching to a conical figure.

Turbinate, or top-shaped; inversely conical; as the disk of Nelumbium.

Pyriform, or pear-shaped; slender and elongated, gradually thickening towards the summit; as the ovary of Œnothera biennis, &c.

Globose (*spherical*); forming nearly a true sphere.

Spheroidal; spherical and somewhat flattened at each end.

Ovoidal, or ovoid; egg-shaped.

Lenticular; having the figure of a double convex lens.

Napiform, or turnip-shaped (page 30. *fig.* 18.).

Fusiform, or spindle-shaped; cylindrical, tapering gradually to each end, as the radish (*fig.* 17.). Sometimes, but improperly, confounded with conical.

Terete; the opposite of angular; usually applied to long bodies.

Cylindrical; terete, and of the same diameter throughout; as the stems of most Endogens.

‖*Cylindraceous;* very nearly cylindrical.

Filiform; cylindrical and as fine as a thread.

Capillary; cylindrical and as fine as a hair.

Tubular; nearly cylindrical and hollow; as the calyx of Pinks.

Fistulous; a hollow body closed at each end; as the leaves and stems of the Onion.

Prismatic, or prism-shaped; having several angles and intermediate flat faces. *Ex.* the Calyx of Mimulus.

Trilateral or *triedral;* a prismatic body of 3 sides or angles.

Quadrilateral or *tetraedral*, of 4 sides or angles, &c.

Trigonous, or three-cornered;
Tetragonous, or four-cornered, &c.; } have the same application as the preceding, being applied to bodies with longitudinal angles and plane faces.

Triquetrous, or three-edged, having three acute angles with intermediate concave faces. *Ex.* Scirpus triqueter. Often confounded with the preceding terms, and also with triangular.

Triangular; expresses a three-angled body without any reference to the form of the intermediate surfaces: it is also applied to the outline of an expanded surface. (See Outline.)—A greater number of angles or sides is expressed by the proper numerals, applied in accordance with the same rules.

Compressed; a solid flattened lengthwise; as the pod of a Pea.

Depressed; flattened vertically; as the fruit of Mallow, Cynoglossum, &c.

Ancipital, or two-edged; compressed with two sharp edges, as the stem of Sisyrinchium.

Carinate, or keeled; furnished with a projecting ridge like the keel of a boat, and usually also concave on the upper surface. *Ex.* the leaves of Hemerocallis or Day-lily, and the glumes of Dactylis glomerata. From this, *boat-shaped* (*navicularis*, *cymbiformis*) scarcely differs.

Canaliculate, or channelled; long and concave, as the leaves of Spiderwort.

Gibbous; presenting a strong convexity.

Plane; presenting two flat and even surfaces as most leaves.

||*Pulvinate*, or cushioned; convex and rather flattened.

||*Sabre-shaped* (*acinaciformis*); as the leaves of Mesembryanthemum acinaciforme.

||*Axe-shaped* (*dolabriformis*); as the leaves of Mesembryanthemum dolabriforme.

||*Tongue-shaped* (*linguiformis*); long, fleshy, obtuse, and slightly convex; as the leaves of Sempervivum tectorum.

Torose, or knobby; a cylindrical body with an uneven surface, as the pod of Chelidonium.

Torulose; slightly torose.

Moniliform, or necklace-shaped; cylindrical and contracted at regular intervals; as the hairs on the filaments of Spiderwort (*fig.* 14, *b.* and *fig.* 77, *c.*).

Cristate, or crested; furnished with a ridge, resembling the crest of a helmet, or of a Cock. *Ex.* Iris cristata, plicata, &c.

Alate, or winged; furnished with a broad and thin margin; as the seeds of Bignonia, the fruit of Dioscorea, the petiole of Rhus Copallina (*fig.* 51, *b.*), and the stem of Lathyrus latifolius, &c.

Flabelliform, or fan-shaped; plaited like a fan. *Ex.* the leaves of the Palmetto.

Labiate (or bilabiate); two-lipped with an open throat, as in *fig.* 71, *b.* and 72, *e.*

Ringent (*personate*), bilabiate with the throat closed, as in Snapdragon (*fig.* 72. *f.*).—This, as well as the preceding term, is applicable only to the calyx and corolla, which see.

Rotate, or wheel-shaped; is applied to an organ with a very short tube and a spreading border. *Ex.* the corolla of Veronica and Galium.

Hypocrateriform, or salver-shaped; wheel-shaped with a long tube (*fig.* 72, *b.*), as the corolla of Phlox.

Infundibuliform, or funnel-shaped; as the corolla of Convolvulus (*fig.* 72, *d.*).—*See* page 182.

Trumpet-shaped; tubular, suddenly spreading at one extremity like the mouth of a trumpet. *Ex.* the corolla of Bignonia.

Campanulate, or bell-shaped; as in the corolla of Campanula (*fig.* 72, *e.*).—*See* page 182.

Urceolate, or pitcher-shaped; campanulate but narrowed at the orifice; as the calyx of Rosa, the corolla of Vaccinium corymbosum, &c.

Cyathiform, or cup-shaped; turbinate and hollow; as the calyx of Molucella lævis of gardens.

Umbrella-shaped; resembling an expanded umbrella; as the stigma of the Poppy and Sarracenia.

Cucullate, or hooded: a plane body, the apex or sides of which are rolled inwards, as the spathe of Arum, the leaves of Viola cucullata, &c.

Turgid; slightly swelling.

Ventricose; swelling unequally on one side; as the corolla of Bignonia, the seed-vessel of Asclepias Syriaca, &c.

Inflated, or bladdery; thin, membranaceous, and equally swelling, as if inflated with air. *Ex.* the calyx of Silene stellata, the lower petal of Cypripedium, and the seed-vessel of Staphylea.

Regular; when all the parts of a series are symmetrical.

Irregular; when the symmetry of an organ is destroyed by the inequality of its parts; as the corolla of the Violet, of Cypripedium, and of all Labiate plants.

Normal; when the ordinary structure of a genus or family is not departed from.

Abnormal; when some departure from the usual structure takes place. Thus, the normal structure of Flowering plants is to have the stamens equal to, or some multiple of the number of the sepals or petals. Scrophularineous plants, however, exhibit 4 stamens, with a five-petalled corolla and a five-sepalled calyx; their structure is therefore abnormal as compared with the type of Exogenæ. The normal structure of Scrophularineæ is to have 4 didynamous stamens, but Pentstemon has a fifth sterile stamen, and Verbascum presents 5 stamens of nearly equal length. These two genera are, therefore, abnormal members of the order Scrophularineæ.

B. *With respect to outline, or circumscription: i. e.* the figure represented by the margin of a body.

Linear; straight and narrow, with the two opposite margins parallel; as the leaves of many Grasses &c.—(*fig.* 41, *a.*).

Ligulate, ‖*lorate,* or strap-shaped; linear and considerably elongated.

Lanceolate; narrowly oblong, and tapering to each end.

Oblong; obtuse at each end, and twice or three times longer than broad, with an elliptical circumscription (*fig.* 41, *b.*).

Oval (elliptical); shorter than oblong in proportion to the breadth, the margin representing a regular ellipse, the two ends tapering equally.

Ovate; similar to oval or oblong, except that the lower end is broadest, so as to resemble the longitudinal section of an egg (*fig.* 41. *c.*).

Orbicular; with a circular outline, as the leaves of Habenaria orbiculata, and Hydrocotyle umbellata (*fig.* 52, *d.*).

Roundish (*rotundus, subrotundus*); approaching the orbicular form, as the leaves of Beupleurum rotundifolium.

Spatulate; oblong, or obversely ovate, with the lower end much attenuated (*fig.* 46, *h.*).

Cuneiform, ‖*cuneate,* or wedge-shaped; broad and obtuse at the summit, regularly tapering nearly to a point at the base. *Ex.* the leaflets of Comaropsis fragarioides.

Subulate, or awl-shaped; linear and very narrow, regularly tapering from a broadish base to a very fine apex; as the leaves of Salsola Kali.

Acicular, ‖*accrose,* or needle-shaped; linear and very narrow, tapering into a fine point from a narrow base; as the leaves of Juniperus communis.

Setaceous, or bristle-shaped; nearly the same as the preceding, but not so sharp-pointed.

Ensiform (‖*gladiate*), or sword-shaped; is applied to erect, linear or band-shaped, nearly straight leaves having slightly convex surfaces, neither of which can be called upper or under, the apex being acute. *Ex.* the leaves of most species of Iris.

Falcate; linear or any elongated form, more or less curved like a scythe or sickle, with the edges parallel; as the leaves of Salix falcata, and the pods of Arabis Canadensis.

Rhomboid; oval, a little angular in the middle, thus approaching the form of a rhomb; as the leaves of Trilium erectum.

. *Deltoid;* a body exhibiting a triangular outline with plane faces, like the Greek Δ. The term, as defined by Linnæus, is applicable to the outline of a flat leaf; but for its illustration he refers to a triangular solid leaf with plane faces: so in most succeeding authors the term is applied to a solid body a transverse section of which exhibits an equilateral triangular outline.—The term *triangular*, it should also be observed, though generally used to express a solid body, is sometimes applied to the outline of a leaf. *Ex.* Chenopodium Bonus Henricus.—The term *trigonous* is applicable to solids only, and not to the outline of an expanded body.

Trapeziform; applied to a leaf, &c. with 4 sides, the opposite ones not being parallel.

Cordate, or heart-shaped; ovate, with two rounded lobes at the base; as in *fig.* 47.

Reniform, or kidney-shaped; differs from heart-shaped in being broader than long, and obtuse at the summit; as the leaves of Asarum Canadense.

Auriculate, or eared; having two small projecting rounded lobes at the base; as the leaves of Rumex Acetosella and Magnolia auriculata.

Hastate, or halbert-shaped; somewhat triangular, with projecting lobes perpendicular to the petiole (*fig.* 48, *b.*); as the leaves of Polygonum arifolium.

Sagittate, or arrow-shaped (‖arrow-headed,); triangular, the lobes at the base elongated and scarcely diverging, as the ordinary leaves of Saggittaria sagittifolia (*fig.* 48, *a.*), of Polygonum sagittatum, &c.

Panduriform (*panduriformis*, *panduratus*), or fiddle-shaped; oblong, and broad at the extremities, but contracted in the middle; as may occasionally be seen in the leaves of Convolvulus panduratus.

Attenuate, or tapering; gradually diminishing in breadth.

Equilateral, or equal; when the two sides are symmetrical; as the leaf of an Apple.

Inequilateral, or unequal; when the two sides are unsymmetrical; as in Begonia (*fig.* 52, *a*).

Oblique; slightly unequal-sided; as the leaves of the Elm.

Dimidiate, or halved; when one half of the figure is wholly or nearly wanting.

C. *With respect to the apex or point.*

Obtuse, or blunt; with a rounded summit; as the leaf of Asclepias Syriaca, &c.

Rounded; very obtuse; as the leaves of a Nuphar or Yellow Water-lily.

Truncate; having the extremity cut off, as it were, by a transverse line; as the leaf of the Tulip-tree, and the lobes of the leaves of Convolvulus Sepium.

Præmorse, or bitten; truncate with a ragged outline, as if bitten by an animal.

Retuse; ending in a shallow, rather broad notch; as the leaves of the white Clover.

Emarginate, or nicked; ending in a small and narrow notch, like a crenature; as the leaves of the Box (*Buxus sempervirens*) and Bladder Senna.

Eridentate; truncate or blunt, with three projecting teeth; as the leaf of Potentilla tridentata.

Obcordate; having a rather deep sinus at the summit, and two rounded lobes; the same as cordate reversed. *Ex.* the leaflets of Oxalis Acetosella, Trifolium repens, &c.

Capitate, or headed; suddenly thickened at the extremity; as the style of many plants, glandular hairs (*fig.* 15, *a*), &c.

Acute; terminating in an acute point, without tapering sensibly.

Acuminate, or taper-pointed; prolonged into an acute point (*fig.* 44, *b*). *Ex.* the leaves of most Poplars.

Apiculate; abruptly prolonged into a short acute point, of nearly the same consistence as the remainder of the organ.

Mucronate; abruptly terminating in a short rigid point, formed of a prolongation of the midrib; as the leaflets of Vicia sativa, Galium Aparine, &c.

Cuspidate; more gradually prolonged into a rigid point; as the leaves of Galium asprellum.

Pungent; terminated in a hard sharp point; as the leaves of Thistles.

Bristle-pointed (*setose*); terminating in a fine sharp point or bristle; as the paleæ of many Grasses, the leaves of several Mosses, &c.

Awned (*aristate*); terminating in a hard bristle or beard, which is often twisted or bent. The awn proper, as in the paleæ of Grasses, often separates from the lamina below the apex (*fig.* 62, *c*, *d*).

Cirrhous; terminated by a filiform, flexuose appendage; as the leaf of Gloriosa, the petiole of the Pea, &c.

Uncinate, or hooked; terminated by a point which is suddenly turned back, forming a hook.

Caudate, or tail-pointed; with a very long weak acumination, like the tail of some animal; as the leaves of several Mosses.

Rostrate, ‖*rostellate*, or beaked; terminated by a long and firm prolongation; as the pods of the Unicorn-plant.

Pointless, (*muticus*); used in contradistinction to any of the terms indicating a pointed apex.

2. As to Division.

A. *With respect to margin.*

Entire (*integerrimus*); when the margin is free from all division; as in the leaves of most Endogenous plants, all Rubiaceæ, Gentianeæ, &c.—*See* also *fig.* 40, 44, and 46, *h*.

Undivided (*integer*); opposed to incised, cleft, or lobed; but applicable to crenate, serrate, or dentate leaves, &c.—By adopting the words entire and undivided in place of the Latin terms, integerrimus and integer, we avoid the absurdity of saying *very entire*.

Crenate; when the margin is furnished with rounded teeth, as the leaves of Glechoma hederacea, &c. *See* also *fig.* 45, *d.* and 52, *b. c. d.* Some leaves are doubly crenate (‖bicrenate), the larger crenatures being also crenated; as those of Malva rotundifolia.

Serrate, or saw-toothed; having acute teeth pointing towards the apex (*fig.* 36, 39, *b. &c.*).

A body furnished with very fine serratures is said to be *serrulate;* as in *fig.* 41, *a.*

Dentate, or toothed; beset with regular, acute or rather obtuse, projecting teeth, not pointing towards the apex; as in *fig.* 46, *f.*

Denticulate; minutely dentate.

Erose; having a jagged or irregularly cut margin, as if gnawed by an animal.

Undulate, or wavy; exhibiting an unequal margin, which may be represented by a wavy line.

Repand; wavy, exhibiting minute salient angles as in *fig.* 46, *g.*

Angled; having several salient angles along the margin; as the leaves of Datura Stramonium.

Sinuate; having an uneven margin, which is represented by a deep wavy line, the teeth and the sinuses being both rounded; as the leaf of many Oaks (*fig.* 46, *e.*).

Lyrate, or lyre-shaped; furnished with several sinuses on each side, gradually diminishing in size to the base; as the leaf of Barbarea vulgaris.

Runcinate; deeply toothed, sinuate, or lobed, the teeth or lobes pointing back towards the base; as the leaf of the Dandelion (*fig.* 46, *d.*).

B. *With respect to incision.*

Incised, regularly divided by deep acute incisions: a general term not expressing the particular kind of division.

Laciniate, divided by deep incisions; the portions (laciniæ) being quite slender and numerous. *Ex.* the leaves of Dentaria laciniata.

Lobed; divided, more deeply than toothed, by somewhat obtuse incisions of uncertain depth: each portion is termed a lobe. The number of lobes is sometimes specified; as 2-*lobed*, the leaf of Bauhinia (*fig.* 53.); 3-*lobed*, as the leaf of Hepatica; 5-*lobed*, as the leaf of the Sugar Maple (*fig.* 39, *a.*), &c.

Cleft (*fissus*); divided to about half the length or breadth of the body. We say *bifid*, or 2-cleft; *trifid*, or 3-cleft; *quadrifid*, or 4-cleft, &c.; and, when the portions or lobes are numerous or indefinite, *multifid*, or many-cleft.

Parted, (*partitus*); divided beyond the middle, but not quite to the base; as the leaves of Trollius, and of many species of Ranunculus (*fig.* 45, *b.*).

Divided (*sectus*); cut quite to the base. As applied to leaves, the term denotes that the incision extends to the midrib or petiole, the parenchyma being interrupted; as in the feather-veined leaves of Cardamine pratensis and hirsuta, the palmate of the Monkshood, &c.—Divided simple leaves are often confounded with compound leaves. *See* page 77.—The portions of a divided leaf are called *segments*.

Palmate; is applied in general to a lobed or incised, radiated-veined body: the lobes being often 5 in number, the whole bears some resemblance to a hand with the fingers widely spread. *Ex.* the leaves of Viola palmata, Passiflora cærulea, &c., and also the tubers of some species of Orchis (*fig.* 22.), &c. The degree of division is expressed by combining the term with the several preceding ones; thus giving rise to the following, viz:

Palmately cleft (*palmatifidus*); cleft in a palmate manner.

Palmately lobed (*palmatilobatus*); as in *fig.* 45. *c.*

Palmately parted (*palmatipartitus*); as the leaves Anemone Pennsylvanica, and of many Ranunculi, (*fig.* 45, *b.*).

Palmately divided (*palmatisectus*); palmately cut quite to the petiole, separating the lamina into several portions, as Anemone Virginiana, Delphinium consolida, &c.

Pedate; palmate, with the side-lobes 2-cleft, having a resemblance to a bird's claw; as the leaves of Arum Dracontium, Viola pedata, &c.

Digitate, or fingered; the same with palmately divided as usually employed; but more properly restricted to compound leaves, &c. *See* ensuing section, and also page 89.

Pinnatifid, or pinnately cleft; is a general term applied to a feather-veined leaf or other body, with deep and regular side incisions. For rigorously distinguishing the degree of division in this respect, as in the analogous case of radiated-veined leaves, &c., we say:

Pinnately lobed (*pinnatilobatus*); when the leaf is thus divided to an uncertain depth—the lyrate form is a mere modification of this.

Pinnately cleft, or *pinnatifid;* when the lobes are cut half-way to the midrib, as in *fig.* 46, *c.*

Pinnately parted (*pinnatipartitus*); when the lobes are divided beyond the middle, the parenchyma, however, not being interrupted; as in *fig.* 46, *b.*

Pinnately divided (*pinnatisectus*); when the lobes are divided quite to the midrib, the parenchyma being interrupted; as the leaves Cardamine hirsuta, &c. This is often confounded with pinnate.

Bipinnately divided, *parted*, or *cleft*, and

Tripinnately divided, *parted*, or *cleft*, &c., are respectively analogous to bipinnate and tripinnate among compound leaves.

Pectinate, or comb-shaped; is applied to a pinnately parted body with numerous narrow and close segments; as the leaves of Proserpinaca pectinata.

C. *With respect to composition or ramification.*

Simple ; not divided or branched.

Compound ; as opposed to simple means branched or divided ; as applied to leaves, *see* page 87.

Branched (‖ ramose) ; divided into many branches ; as the stem of Hypericum Sarothra, H. prolificum, &c.

Forked, or ‖ *furcate* ; divided into two branches.

Dichotomous ; many times forked, the divisions being always in pairs ; as the stems of Chickweeds.

Trichotomous ; forked with the branches in threes ; as the stem of Mirabilis Jalapa.

Stellate, or star-shaped: several branches radiating from a common centre ; as the hairs of the Mallow tribe, &c. (*fig*. 14, *f*.).

Articulate, or jointed ; furnished with joints at which the body falls in pieces, or is capable of separating more easily than elsewhere ; as the pod (*loment*) of Desmodium ; the leaflets of a compound leaf, &c. It is often loosely applied to bodies having the appearance of being jointed, but not so in reality ; as the leaves of Juncus polycephalus, the stem of Cyperus articulatus, Scirpus equistoides-*Elliott.*—The latter may be termed *nodose* or knotted. *Nodes*, as those of the culms of Grasses, &c., are sometimes called joints, but quite improperly.

Decompound and *Supradecompound ;* applied to petioles or branches, denotes that they are several times branched, without specifying the mode, *Ex*. the petioles of Thalictrum, Aralia racemosa,&c.

The term *compound* as applied to leaves is explained on page 85 ; and it has already been observed that all compound leaves are reducible to two principal kinds, viz: the *digitate*, and the *pinnate*. A leaf is

Digitate ; when the several leaflets arise from the very summit of the petiole ; as in the Horse-chestnut (*fig*. 49 *a*.), the Lupine, &c., and

Pinnate ; when the leaflets are arranged along each side of a common petiole ; of which the chief modifications are

1. *Alternately pinnate ;* the leaflets being alternate ; as in Gymnocladus Canadenis and Amorpha fruticosa.
2. *Oppositely pinnate ;* the leaflets being opposite, as in most cases.
3. *Interruptedly pinnate ;* the leaflets alternately large and small, as in the Potato.
4. *Abruptly,* or *equally pinnate ;* when the petiole is terminated neither by a tendril or by leaflets ; as in the species of Cassia.—*See fig.* 40, *b.*
5. *Unequally pinnate* (*imparipinnatus*) ; pinnate with a single terminal leaflet; as in Roses, Robinia Pseudacacea or Common Locust, &c.
6. *Pinnate with a tendril ;* when the petiole is prolonged into a tendril; as in the Pea, the Tare (*Vicia*), &c., (*fig.* 50, *a.*).

As to further composition, pinnate leaves are

Bipinnate ; when the secondary petioles bear the leaflets ; as in Acacia Julibrisson, &c., (*fig.* 50, *e.*).

Tripinnate ; when the third order of petioles bear the leaflets, as in *fig.* 50, *d.*

Conjugately pinnate ; when the secondary petioles bearing the leaflets, proceed in twos from the summit of a common petiole.

Digitately pinnate ; when several secondary petioles bearing leaflets along their sides, part from the summit of a common petiole. *Ex.* The Common Sensitive plant.—This is best comprehended by supposing the feather-veined leaflets of a digitate leaf, like the Horse-chestnut, to become compound. The preceding is but a modification of the present form.

The leaflets of a pinnate leaf considered as pairs are said to be,

Unijugate, 1-jugate, or one pair ; when the petiole bears but a single pair of leaflets.

Bi—or *2-jugate,* when it bears 2 pairs, and *3-4-5-jugate,* according to the number of the pairs. When the number is quite considerable, the term *multijugate* or many-paired is employed.

Or, we may express the number of leaflets, whether of a digitate or pinnate leaf, without reference to the pairs; as—

Unifoliolate; with a single leaflet—(*see* page 89); as in the Orange, Rynchosia monophylla, &c.

Bifoliolate (‖*binate*); with the petiole bearing 2 leaflets.

Trifoliolate (usually called *ternate*); with 3 leaflets; as in the Clover, Bean, Desmodium, &c.

Quinquefoliolate (usually called *quinate*); with 5 leaflets; as some Lupines, Ginseng (*Panax quinquefolia*), &c.

To distinguish in these instances between the digitate and the pinnate series reduced to one, two, three or five leaflets, those of the first kind are called digitately, of the second, pinnately 1-2-3-5-foliolate—(*See* page 89).

3 Of Surface.

A. *With respect to marking, or evenness.*

Reticulated, or netted; covered with a net-work of lines in slight relief; as the seeds of the Prickly poppy (*fig.* 109, *d.*).

Pitted (*scrobiculate*); having numerous shallow depressions; as the receptacle of most Compositæ.

Lacunose; having large and deep depressions.

Alveolate, ‖*favose*, or honey-combed; having deep excavations, resembling honeycomb; as the receptacle of many Compositæ. *Ex.* Balduina, *Nutt.*

Rugose, or wrinkled; as the leaves of the garden Sage, when the veins being contracted the surface rises irregularly above them.

Scarred; marked by the scars of bodies that have fallen off. Thus a stem often presents scars left by former leaves.

Striate; marked by longitudinal lines; as the stems of most Grasses, of Equisetum (182), &c.

Furrowed (*sulcate*); marked by longitudinal furrows; as the stem of the Parsnip, &c.

Even; opposed to inequality of surface.

B. *With respect to appendages, or superficial processes.*

Unarmed; destitute of spines or prickles.

Spinose; furnished with spines; as the stem of Cratœgus or Thorn, the leaves of Holly, &c.

Prickly; furnished with prickles; as the stem of the Gooseberry & Rose.

Echinate; beset with numerous straight and slender prickles; as the cupule of the Chestnut, the capsule of Argemone Mexicana, &c.

Muricate; beset with short excrescences having a broad base and a sharp point.

Tuberculate (*verrucose*); covered with little excrescences or warts.

Pappillose, or pimpled; scarcely different from tuberculate; sometimes applied to rather soft minute excrescences.

Scabrous (*scaber*, *asper*, *exasperatus*), or rough; furnished with minute asperities, evident to the touch, but scarcely or not at all perceptible to the naked eye. *Ex.* the leaves of Lithospermum officinale, the stems of Scouring-Rush.

Pubescent; covered with short soft hairs.—This term is sometimes used generically for all kinds of hairiness.

Pilose, or hairy; covered with rather firm hairs, standing nearly at right angles with the surface on which they grow.

Villous (*villose*); thickly clothed with long, soft and straight hairs, lying nearly flat, or at least not standing at right angles with the surface.

Hirsute; clothed with long, rigid, straight and spreading hairs or bristles.

Strigose, is usually employed synonymously with hispid. Willdenow, however, applies it to a surface covered with appressed rigid hairs.

The five preceding terms are variously defined by different authors, and still more variously applied in description. De Candolle being nearly uniform in the use of these terms, I have adopted his definitions.

Lanate, *lanuginose*, or woolly; densely covered with long, soft, matted hairs; as the leaves of the Common Mullein.

Tomentose; densely clothed with rather short, crisped and matted hairs; as the fruit of the Peach.

Velutinous, or velvety; having a covering of very short, dense, rather rigid hairs, so that the surface resembles that of velvet; as the stem and leaves of Sida Abutilon.

Sericeous, or silky; covered with very fine, close-pressed hairs, so as to exhibit a satiny appearance; as the lower side of the leaves of Potetilla anserina.

Canescent (*incanus*), or hoary; densely clothed with very short, appressed hairs, giving the surface an uniform appearance of whiteness; as the stem and leaves of Pycnanthemum incanum.

Lepidote, or leprous; covered with minute scales consisting of stellate hairs grown together (*fig.* 15. *e.*); as the leaves of Shepherdia, Croton argyranthemum, &c.

Scaly (*squamose*),
Chaffy (*palaceous*), } are both usually applied to abortive and scaly or chaff-like rudiments of leaves (as those on the stem of Elytraria, and the receptacle of Compositæ), rather than to appendages of the cuticle.

Scurfy; covered with minute white scales or scurf;—a kind of desquamation of the cuticle; as the leaves of Atriplex, Chenopodium album, &c.

Farinose, *pulverulent*, or mealy; covered with a minute white scurf, or powder, detached by the touch; as the leaves of Populus candicans, Primula farinosa, &c.

Bearded (*barbatus*, *crinitus*); having tufts of long hairs, or solitary bristles, growing from any part of the surface.

Arachnoid, or cobwebby; bearing fine, very slender, entangled hairs; as the paleæ of Agrostis arachnoidea. *Elliot.*

Ciliate; having a row of fine bristles or hairs at the margin, which thus resembles the eyelash; as the petals of Tropæolum, the leaves of the House Leek (*Sempervivum*), Convallaria umbellulata, *Michaux*, &c.

Fimbriate, or fringed; when the margin is bordered by filiform processes thicker than hairs, usually of the same texture as the organ which bears them. *Ex.* the petals of Silene stellata, Habenata ciliaris, fimbriata, &c.

Plumose, or feathered; is applied to a body furnished with two rows of hairs, like a plume; as the stigma of Avena elatior, and other Grasses, the bristles of the pappus of the Dandelion, &c.

Glandular or *glandulose;* furnished with glands, or glandular hairs (*fig.* 15, *a*, *b*.); as the flower-stalk and calyx of Roses and Fraxinella, the leaves of Drosera, &c.

Stinging; furnished with stings (18. *fig.* 15. *c*, *d*.); as the Nettle.

Glabrous; smooth; opposed to every kind of hairiness, silkiness, scaliness, scurfiness, &c.

C. *With respect to polish.*

Smooth (*lævis*, *lævigatus*); free from all asperities and unevenness, as well as hairiness, as many leaves, fruits, &c. Not synonymous with glabrous, since a glabrous surface may be uneven.

Shining (*nitidus*, *lucidus*); smooth and polished as the leaves of Habenaria orbiculata.

Dull; the reverse of shining; smooth without polish.

Vernicose, or varnished; shining as if by a coat of varnish.

Naked; expresses the absence of appendages. It is not usually applied to surfaces destitute of hairiness, but is often opposed to *scaly* or *spinose:* or still more commonly it expresses the absence of an organ or covering generally present. Thus, a flower is said to be naked when it has no calyx, a seed when destitute of seed-vessel, and a bud when furnished with no scaly covering.

Glaucous; covered with a fine waxy powder which easily rubs off. *Ex.* a Cabbage-leaf.

Viscid, viscous, or *glutinous;* covered with a glutinous exudation.

Mucous; covered with a slimy excretion.

4. *Of Texture.*

Membranaceous; thin, flexible, and slightly translucent; as the leaves of Mosses.

Scarious; dry, thin, and colorless; as the involucral bracts of Centaurea Americana.

Papery (*chartaceus*); having the consistence of writing paper, and quite opaque; as most leaves.

Coriaceous, or leathery; having the consistence of leather; as the leaves of the Misletoe.

Crustaceous; hard, thin, and brittle.

Cartilaginous; hard and tough.

Corky (‖*suberose*); having the texture of cork.

Spongy, cellular and dry.

Horny; having a hard, close texture, but capable of being cut with a knife; as the albumen of Umbelliferæ.

Bony or osseous, as the stone of a peach.

Fleshy, as the apple.

Waxy, as the pollen of Asclepias, Cypripedium, &c.

Succulent; cellular and juicy; as the torus of the Strawberry, the leaves of the Prickly-pear, &c.

Fibrous; having a large proportion of woody fibre in its composition; as the rind of a Cocoa-nut.

Herbaceous; green and cellular, as the tissue of most leaves; applied to herbs in contradistinction to shrubs and trees.

5. Of Size.

Most of the terms relating to this quality are the same as those in common use; but a few having a particular application need to be defined. The following are of this kind.

Dwarf (*nanus, pumilus, pygmæus*); small and short, as compared with other species of the same genus.

Very small (*pusillus*) ; similar to the last but very slender.

A span (*dodrantalis*) ; nine inches; or tho span included between the thumb and little finger, separated as widely as possible.

A foot (*pedalis*) ; twelve inches; the length of a tall man's foot.

A Cubit ; seventeen inches ; or the distance between the elbow and the tip of the fingers.

An ell (*ulnaris*) ; twenty-four inches, or the length of the arm.

A toise (*orgalis*) ; six feet, or the ordinary height of man.

6. Of Duration.

Besides the terms in ordinary use for expressing duration, there are several peculiar to botany, some of which have been recently introduced by De Candolle.

Monocarpous ; bearing flowers and fruit but once, and dying soon after. Those living but a single year are called *annuals ;* those which endure for two years are termed *biennials.* Some plants, such as Agave Americana, live several years before flowering, but die soon afterwards.

Polycarpous, or *perennial ;* living for several years, and capable of bearing flowers and fruit many times.

When the stem endures several years, as in trees and shrubs, the plant is said to be *caulocarpous.*

When the stem perishes annually quite down to the ground, the root enduring several years, as in many herbs, the plant is said to be *rhizocarpous.*

Hysteranthous ; when the flowers appear before the leaves; as the Alder, Maple, Colt'sfoot (*Tussilago Farfara*), &c.

Synanthous ; when leaves and flowers appear at the same time ; as the Apple.

Proteranthous ; when leaves appear before the flowers.

Deciduous; finally falling off.

Caducous; falling off very early. Thus the calyx of the Poppy is caducous, falling off when the corolla expands; and the calyx of the Mustard and all Cruciferous plants, falling off at the same time with the petals, is said to be *deciduous.*

Persistent; not falling off, but remaining until maturity; as the calyx of Labiatæ, Caryophyllaceæ, &c.

Marcescent; withering without falling off; as the flowers of Hemerocallis, the leaves of Beech and Hornbeam.

Fugacious; perishing or falling off at a very early period, as the petals of Helianthemum.

7. Of Color.

Owing to the great predominance of green in the vegetable kingdom, all organs which do not present this hue are said to be *colored:* green parts are often said to be *uncolored.*

All the hues presented by plants may be arranged under 8 principal colors; viz. White, gray, black, brown, yellow, green, blue, and red. The best arrangements of the tints, as applied to plants, are those of De Candolle (*Théorie Elémentaire*) and Lindley (*Introduction to Botany*), the latter being chiefly compiled from the former and the *Terminology* of Bischoff.

I. White (*albus;* in terms taken from the Greek *leuco-*).

Snow-white (*niveus*); the purest white.

Pure white (*candidus* in Greek compounds *argo-*); not quite so clear as the last.

Ivory-white (*eburneus*); white with a slight tint of yellow.

Milk-white (*lacteus;* Gr. comp. *galacto-*) white, verging to blue.

Chalk-white; very dull white, with a touch of gray.

Silvery (*argenteus;* Gr. comp. *argyro-*); white with a tint of bluish gray, and considerable lustre.

Whitish (*albidus*); white a little soiled.

Turning white (*albescens*); changing to a whitish cast from some other color.

Whitened; slightly covered with white on a darker ground.

II. Gray.

Ash-gray, or *cinereous;* a mixture of pure white and pure black, forming an intermediate tint.
Pearl-gray, (*griseus*); gray a little verging to blue.
Slate-gray; more decidedly bordering on blue.
Lead-colored, or *plumbeous;* bluish gray with considerable lustre.
Smoky; brownish gray.
Mouse-colored; gray with a touch of red.
Hoary, or *canescent;* grayish white, caused by a minute appressed pubescence. *See* § 3. B.

III. Black.

Pure black (*ater, niger;* Gr. comp. *melano-*)
Coal-black; a little verging upon blue.
Pitch-black (*piceus*); black changing to brown.
Raven-black (*pullus*); black with a strong lustre.
Blackish (*nigrescens*); black tinged with gray.

IV. Brown.

Fuscous; greyish brown.
Deep brown (*brunneus*); a pure dull brown.
Bright brown (*spadiceus*); clear brown, a little shining.
Chestnut-brown (*badius*); dull brown slightly tinged with red.
Ferruginous, or rusty; light brown with a tint of red.
Cinnamon-colored; bright brown with a tint of yellow and red.
Red-brown; brown mixed with red.
Rufous, or ‖*rufescent;* redder than the last.
Liver-colored (*hepaticus*); dull brown and yellow.
‖*Fuliginose;* dirty brown and blackish.
Lurid; dirty brown a little clouded.

V. Yellow.

Yellow (*luteus*, Gr. comp. *xantho-*); as gamboge.
Golden-yellow (*aureus*, Gr. comp. *Chryso-*) pure yellow, but bright.
Pale yellow (*flavus, flavidus, flavescens, lutescens*); a pure pale yellow.
Sulphur-colored, or *stramineous;* very pale dull yellow.
Ochre-color; yellow with a tint of brown.
Ochroleucous ; the last mixed with white.
Orange (*aurantiacus*); yellow mixed with red.
Saffron-colored (*croceus*); orange with a tint of brown.
Tawny, or *fulvous;* dull yellow with a mixture of gray or brown.

VI. Green.

Green (*viridis*, Gr. comp. *chloro-*); the ordinary green of leaves, &c.
Deep green (*atrovirens*); green, with a tinge of black.
Verdigris green (*æruginosus*); deep green with a tint of blue.
Yellowish-green (*flavo-virens*); green mixed with yellow.
Olive-green, or *olivaceous;* green mixed with brown.
Greenish, or *viridescent;* pale green.

VII. Blue.

Cæruleous ; a pure, but rather pale blue.
Cyaneous, or *Prussian blue ;* a pure intense blue.
Indigo ; the deepest blue; scarcely differs from the last.
Sky-blue, or azure; a light pure blue.
Violet ; intermediate between pure blue and red.
Lilac ; a pale dull violet.

VIII. Red.

Red (*ruber;* in Gr. comp. *erythro-*); red in general.

Carmine; the purest red.

Rose-color; pale, pure red.

Flesh-colored (*incarnatus*); paler than the last, and rather dull.

Sanguineous, or blood-red; deep red with a tint of purple.

Purple; dull red mixed with blue.

Scarlet (*coccineus*); a very lively red with a slight tint of yellow.

Flame-colored; fiery red; a lively scarlet.

Cinnabar; scarlet mixed with orange.

Vermilion; scarlet with a tint of yellow.

Brick-color; dull red mixed with gray.

Brown-red (*rubiginosus, hæmatiticus*); dull red mixed with brown.

Copper-color (*cupreus*); brownish-red, with a metallic lustre.

8. Of Variegation, or Marking.

Variegated; the color disposed in irregular spaces.

Spotted (*maculatus, guttatus*); the color disposed in spots or blotches.

Dotted; the color disposed in very small round spots.

Clouded; when colors are unequally blended.

Marbled; traversed by irregular veins of color.

Tessellated; when the color is arranged in small squares.

Bordered (*limbatus*); when one color is surrounded by a broad edging of another.

Margined; when one color is surrounded by a narrow edging of another.

Banded; when there are transverse stripes of color.

Striped (*vittatus*); when there are longitudinal stripes of any color.

Painted (*pictus*); when colors are disposed in streaks of unequal intensity.

Occllated; when a broad spot has another spot of a different color within it.

Zoned; when several circular colored bands are placed within each other.

9. Of Veining.

All the commonly occurring terms relative to veining are defined in the section concerning the structure of leaves (See 53), and need not be repeated here.

II. *Of Individual Relative Terms.*

These refer to *Direction*, or the relation which organs bear to the surface of the earth, or the axis on which they are arranged; and *Insertion*, or the manner in which one organ is attached, or adherent to another.

1. Of Direction.

Erect; perpendicular to the earth.

Straight ; opposed to curved or bent.

Strict; very straight; as applied to a stem it denotes it to be straight, erect, slender, and scarcely branched.

Ascending, or ‖*assurgent ;* nearly prostrate at the base, gradually acquiring an upright direction; as the stems of Clover and of many Grasses.

Descending ; having a direction gradually downwards.

Depending ; hanging down by its own weight; as the branches of the Weeping Willow.

Vertical, or perpendicular; at right angles with some other body; as upright stems with the earth, &c.

Horizontal ; parallel with the horizon.

Inverted; when the base points upwards and the summit towards the earth.

Resupinate; when the usual position of an organ is reversed. Thus, a papilionaceous flower is resupinate when the standard is inferior and the keel superior, as in the Pea-nut (*Arachis hypogæa*). So, also, in some Labiate and Schrophularineous plants that which is ordinarily the upper lip is below; as in Scrophularia. In Orchideous plants this resupination is plainly caused by the twisting of the pedicels.

Inclined; not erect.

Reclined; gradually back from the perpendicular; as the branches of the Elm (*Ulmus Americana*).

Declined; turned to one side, or deviating from the perpendicular by a curve; as the stamens of Rhododendron nudiflorum, &c.

Pendulous; hanging perpendicularly downwards, as the flowers of the Balsam (*Impatiens pallida, &c.*)

Drooping, or *nodding* (*cernuus, nutans*); hanging downwards, not perpendicularly, but intermediate between that and the horizontal direction; as the flowers of Lilium Canadense, Geum rivale, the Snow-drop, &c.

Convolute; rolled up.

Involute; rolled inwards.

Revolute; rolled backwards.

Inflexed, or *infracted;* suddenly bent inwards.

Deflexed; suddenly bent downwards.

Incurved; more gradually turned inwards.

Recurved; curved backwards.

Secund; turned to one side; applied to the flowers of a spike or raceme, when they all take the same direction by the turning of their pedicels. *Ex.* Pyrola secunda, Digitalis purpurea, &c.

Flexuose; bending alternately inwards and outwards; as the rachis of Wheat, Barley, &c.

Tortuous; bending irregularly in several directions.

Geniculate; bent abruptly; as the culms of many Grasses, the pedicels of Streptopus amplexifolius and roseus, &c.

Spiral; twisting like a corkscrew; as many tendrils.

Circinate or *gyrate;* rolled up from the apex, as the young fronds of Ferns.

Twining, or *voluble;* twisting around some other body; as the stem of the Morning glory, the Hop, &c.

Climbing, or *scandent;* elevating itself without twining, by means of other bodies; as Clematis Virginiana, &c.

Retrorse; turned backwards, the apex pointing towards the base of the organ on which it stands.

Introrse; turned inwards; as the anthers of the Lily.

Extrorse; turned outwards; as the anthers of Iris.

Procumbent; this is said of stems when they spread over the surface of the ground; as Lespedeza procumbens, Desmodium rotundifolium, &c.

Repent; procumbent and putting forth roots; as Glechoma hederacea, Poa reptans, *Michx.*, &c.

Decumbent; reclining upon the earth, but with the apex ascending; as the stems of Desmodium obtusum.

Prostrate; lying flat upon the earth; as the leaves of Habenaria orbiculata.

Diffuse; spreading widely.

Divaricate; spreading nearly at right angles with the axis; as many branches with the trunk.

Brachiate; when branches proceed from a common axis, nearly at right angles, alternately in opposite directions. *Ex.* Hypericum prolificum and Kalmianum.

Spreading; gradually turned outwards; as the petals of a Rose.

Converging, or *connivent;* gradually turned inwards; as the sepals of the Globe-flower (*Trollius Europæus*).

Swimming; floating under water; as Sea-weeds.

Floating; lying on the surface of water; as the leaves of the Water-lily.

Submersed; growing under water.

Emersed; raised above the water; as the flowers of the Water-lily, Pond-weed, &c.

2. Of Insertion.

A. With respect to the mode of attachment or adhesion.

Pellate (‖*umbilicate*); fixed to its stalk by the centre, or some point distinctly within the margin. *Ex,* the leaf of Tropæolum (*fig.* 42, *b.*), and of Hydrocolyte umbellata and interrupta (*fig.* 52. *c. d.*).

Sessile; without a stalk; as the leaves in *fig.* 53, the flower of the Prickly-pear (*Cactus Opuntia*), the anthers of Pondweed, and the stigmas of Trillium.

Decurrent; prolonged beyond the point of insertion; as the leaves of the common Mullein, which appears to run along down the stem.

Amplexicaul, or clasping; applied to leaves embracing the stem by their base; ***Ex.*** Campanula amplexicaulis, Streptopus roseus. *Semi-amplexicaul* is the same in a lesser degree.—***Ex.*** Poppy, Convallaria stellata and multiflora.

Vaginate; clasping by a sheath, as the culms of Grasses.

Perfoliate; when the posterior lobes of a clasping leaf are united, so that the stem appears to pass through the substance of the leaf. ***Ex.*** Streptopus amplexifolius (*fig.* 52, *e.*), Bupleurum rotundifolium, Uvularia grandiflora and perfoliata.

Connate; when the bases of two opposite leaves are united together; as in Eupatorium perfoliatum, and the upper leaves of Lonicera Caprifolium, sempervirens, parviflora, &c.

Adnate; adhering to the face of anything; as the anther to the filament in the Crowfoot and Water-lily tribes.

Innate; adhering to the apex of anything; as the anther to the filament in the Poppy tribe, &c.

Versatile; adhering by the middle to the pointed apex, as on a pivot, so as to be nearly balanced ***Ex.*** the anthers of Grasses, the Lily, Tulip, &c.

Stipitate; elevated on a little stalk (not applied to leaves and flowers); as the ovaries of Coptis (*fig.* 79, *d.*), the pappus of Tragopogon, &c.

Articulated, or jointed; when one part is joined to another by a manifest articulation; as the leaves of most Exogens to the stem.

Free; not cohering with anything, as the ovary and fruit of the Poppy, &c.

Distinct; free from each other; as the carpels of Ranunculus, Caltha, &c.

B. *With respect to situation.*

Dorsal; fixed to the back of anything.

Lateral; fixed to the side of anything.

Marginal; fixed upon the edge of any organ.

Basal; fixed on the base of anything.

Radical, arising from the root. This, when said of leaves and flowers is not strictly correct, since what are called radical leaves, &c., arise from the collet or base of the stem, and not from the root.

Cauline; arising from the stem.

Axillary; arising from the axillæ of the leaves or branches. *Ex.* the flowers Streptopus, Convallaria multiflora, Lonicera ciliata; the solitary flower of Podophyllum peltatum, &c.

Rămeal; belonging to the branches.

Floral; belonging to the flower.

Epiphyllous; inserted on the leaf.

Terminal; proceeding from the end of anything; as flowers from the extremity of a flower-stalk.

Crowning; situated on the top of anything; thus, the limb of a superior calyx is said to crown the ovary.

Epigæous; growing close upon the earth.

Hypogæous, or subterranean; growing beneath the surface of the earth.

Epiphytic; growing on other plants, but not drawing nourishment from their substance; as Mosses, &c., upon trees, and in warm climates many Flowering plants. *Ex.* Tillandsia, Epidendrum Magnoliæ.

Parasitic; attached to, and deriving their nourishment from other plants. *Ex.* the Misletoe, Dodder, &c.

Epigynous,
Perigynous,
Hypogynous, } have a special application, for which *see* Art. 124, *fig.* 75.

II. OF COLLECTIVE TERMS.

Terms which cannot be applied to a single thing, a larger number being necessarily expressed or understood.

1. Of Arrangement.

Opposite; placed on opposite sides of the same body; as the leaves of Labiatæ, Rubiaceæ, Cayophyllaceæ, &c.

Verticillate, or whorled; when several parts are disposed circularly around a common axis; as sepals, petals, and stamens around the ovary, and some leaves around the stem (*fig.* 57, *e.*).

Stellate, or star-shaped; the same as whorled, but usually applied to leaves when they are narrow and acute. *Ex.* Galium.

Ternate; in threes; when three things are placed in opposition around a common axis.

Compound; opposed to simple; formed of many parts composing one common whole. Its particular meaning as applied to leaves is elsewhere given (52, 56).

Loose (laxus); having an open arrangement; as the panicle of Agrostis polymorpha, the common Red-top grass.

Crowded; having a dense arrangement; as the panicle of the Orchard-grass (*Dactylis glomerata*), and Panicum Crus-galli.

Sparse, or scattered; loose, without any definite arrangement; used in opposition to whorled, opposite, &c.

Imbricated; when parts lie over each other in regular order, like tiles on a roof, as the scales of a cupule (*fig.* 61, *d.*), and of the involucre of Centaurea (*fig.* 68, *d.*).

Rosulate; when parts, apparently opposite or whorled by the contraction of the internodes, lie packed over each other like the petals of a rose; as the offsets of Houseleek, the first year's stems of some biennial species of Arabis, Draba, &c.

Radiate; diverging from a common centre; as the outer florets of the Sun-flower.

Cæspitose; forming dense patches or turfs.

Fascicled; when several similar organs proceed (apparently) from a common point; as the leaves of Pinus, Larix, &c.

Distichous, when parts are arranged in two opposite rows; as the florets of Cyperus.

Bifarious, in two rows not necessarily opposite.

Trifarious, in three rows; and so on.

Unilateral, in a single row.

Glomerate, *aggregate*, or clustered: collected in close roundish parcels.

Spiral; spirally disposed along a common axis; as the flowers of Spiranthes.

Decussate; arranged in pairs alternately crossing each other at right angles; as the leaves of Eupatorium perfoliatum.

Fastigiate; level-topped; when the parts form nearly a flat top, as the corymbs of Achillæa.

Squarrose, dense, and spreading at right angles from a common axis; as the involucral leaves of Silphium, Tetragonotheca, and other Compositæ, and the leaves of some Mosses.

Depauperate, or starved; less developed than usual in the family or genus.

Distant, or remote; opposed to dense, approximated, &c.

Interrupted; when the symmetrical arrangement is destroyed; as when portions of a spike or a contracted panicle are not covered with flowers, &c.

Continuous; the reverse of the last, and also of articulated.

Geminate; double; growing in pairs; as the flowers of Linnæa borealis.

2. Of Number.

None; wanting altogether.

Solitary; growing singly, as the flowers of Viola, Sarracenia, the Tulip, &c.

Few; small in number; definite but variable.

Many, or *numerous;* opposed to few; indefinite, or so many that they cannot readily be counted.

The subjoined table (from De Candolle *Théorie Elémentaire*) contains most of the terms used in composition to express the number of parts.

From the Latin.	*From the Greek.*	
Uni	mono	1.
Bi	di	2.
Tri	tri	3.
Quadri	tetra	4.
Quinque	penta	5.
Sex	hexa	6.
Septem	hepta	7.
Octo	octo	8.
Novem	ennea	9.
Decem	deca	10.
Undecim	endeca	11.
Duodecim	dodeca	12.
Viginti	icos	20.
Pauci	oligos,	a small number.
Pluri		a middling number.
Multi	poly,	a great number.
Bini, gemini		two together.
Terni, ternati		three together.
Quaterni		four together.
Quini, quinati		five together.
Seni		six togther.
Septeni		seven together.
Octoni		eight together.
Noni		nine together.
Deni, denarii		ten together.
Duodeni		twelve together.
Viceni		twenty together.
Simplici		simple.
Duplici		double; &c.

These are compounded with the name of the organ whose number is to be expressed—thus:

Uniflora; one-flowered; *biflora:* 2-flowered, &c.
Unifolia or *unifoliata*, & *Monophylla;* one-leaved.
Quinquefolia, or *pentaphylla;* five-leaved.
Pauciflora, or *oligophylla;* few-leaved.
Senifolia; five leaves together, &c.

Care must be taken, however, in these as in all other cases, not to combine Latin and Greek words in the formation of a compound term; all such being inadmissible.

III. OF TERMS OF QUALIFICATION.

Terms are most frequently qualified by the prefix *sub;* which thus employed means somewhat. Thus:

Subovate; somewhat ovate.
Subrotund; nearly round.
Submembranaceous; nearly membranaceous in texture; and so on.
The same qualification is sometimes effected by the termination *escens*, or *escent.* Thus:
Viridescent; greenish.
Glaucescent; slightly glaucous, and so on.

The prefix *ob* indicates inversion: thus:

Obovate; means inversely ovate, as in *fig.* 41, *d.*
Obcordate; inversely cordate, as the leaflets of Oxalis, or Wood-sorrel. But *oboval* and *oblanceolate* have no meaning, the two ends of an oval and lanceolate body being similar.

For expressing an intermediate form or quality, two terms may be united by a hyphen. Thus, *ovate-oblong*, and *ovate-lanceolate*, indicate forms intermediate between ovate and oblong, and ovate and lanceolate. Terms of the same kind only can be thus united; thus we may not write *ovate-acute, long-linear*, or *pinnate-trifoliolate;* but instead we say, *ovate acute; long linear*, and *pinnately trifoliolate.*

IV. Of Signs.

The signs adopted by Linnæus for expressing the duration of a plant are these: ☼ an annual; ♂ a biennial; ♃ a perennial plant, and ♄ a shrub or tree. These are all of the kind met with in the older works.

Of late, several authors have contrived numerous signs; but the following, as established by De Candolle, comprise all which have as yet come into general use.

⊙	A monocarpous plant in general.
①	An annual plant.
②	A biennial plant.
♃	A rhizocarpous plant, *i. e.* a plant capable of bearing fruit many times; the stem dying down to the ground every year.
♄	A caulocarpous, or perennial plant not dying down to the ground yearly.
♂	A staminate flower or plant.
♀	A pistillate flower or plant.
☿	A perfect flower or plant.
?	The note of interrogation affixed to a specific name thus, *Pyrola asarifolia*? signifies that we are not sure that this is the proper name of the plant. If placed thus, *Pyrola? asarifolia*, it would mean that it was doubtful if the plant in question was truly a species of Pyrola. When affixed to the name of an author, as *Pyrola asarifolia*, Michx.? Pursh? Torrey, it indicates that while we are confident the plant under consideration is described by Torrey under this name, we are doubtful if it be the plant thus named by Michaux and Pursh. When the note of doubt has a general application to all the authors quoted, some writers place it at the commencement of the name, as ? *Pyrola asarifolia, Michx. Pursh*, &c.
!	The point of exclamation placed after the name of an author, signifies that we have examined a specimen labelled by the author whose name is cited, and are therefore certain that our reference is correct: thus, *Pyrola asarifolia*, Torrey! This

sign is also used to authenticate a locality, thus, *Cunila glabella, Michx.* Hab. Near Frankfort, Kentucky, *Dr. Short!* signifies that specimens collected by that botanist, at the above specified locality, have passed under our inspection.

† When this mark is annexed to a name it signifies that there is some obscurity resting upon the subject. It is however seldom used.

Abbreviations.

As to abbreviations of the names of organs, and of the titles of works, no special rules are laid down, each writer adopting whatever system best suits his purpose, giving the necessary explanations in the proper place. The names of authors, however, are subject to some rules in this respect. Names of a single syllable should be written out in full. Names of two or more syllables are usually abridged by writing only the first syllable and the first letter of the second. Thus *Linn.* for Linnæus; *Willd.* for Willdenow; *De Cand.* for De Candolle; *Muhl.* for Muhlenberg; *Nutt.* for Nuttall, &c. This rule is sometimes departed from, to avoid a similarity to some other abbreviated name; thus *Michx.* is preferable to *Mich.* for the name of Michaux; the latter being the customary abbreviation forMicheli, an Italian botanist.

APPENDIX.

I. *Of Collecting and Preserving Plants for an Herbarium.*

To any one desirous of obtaining a correct knowledge of the Vegetable Kingdom, little need be said in recommendation of the universal practice of botanists in collecting and preserving in different ways, specimens of whatever plants may fall within the scope of their observation. These collections were formerly called a *Hortus Siccus;* but the name *Herbarium* is now universally adopted. Apart from the actual practical knowledge which a student will necessarily derive from collecting, determining, and arranging a large number of species for himself, a moment's reflection will at once shew that such a collection is absolutely indispensable to all who would attain to any thing like a proficiency in the science of botany. When it is considered that about 80,000 species are already known to botanists, i will be scarcely necessary to add, that no one can pretend to trust to his unassisted recollection, even in respect of plants which have frequently passed unde his observation. Indeed, in the case of large and difficult genera, such for instance as Carex, Salix, &c., i has been found absolutely impossible to define the distinctions between closely allied species, in such precise written terms as shall preclude the possibility c mistake. Hence many errors as to the identity c particular species have been ultimately cleared up b the actual inspection of the plants in the Herbaria the authors who first described them. Were it not f his collections, one half of the year would be lost the working botanist; and, in respect to the student, may be questioned whether he would not without suc assistance forget during the season of winter, a lar proportion of the summer's acquisitions. It is, ho ever, needless to say more upon this point; since even the beginner will very soon experience for himself the absolute necessity of preserving for further and future examination the plants which from time to time he may be able to collect. Specimens have been preserved in spirits; and in the case of ripe pulpy fruits perhaps no better mode can be devised; but for an entire collection it becomes very expensive, and for the purpose of arrangement and reference, so large a number of bottles would be found troublesome and inconvenient. The mode of preservation by drying and pressing, is now therefore universally adopted, as combining the greatest amount of practical utility with the most economy, despatch, and convenience. Our limits will not permit us to go at length into all the suggestions and more minute details which different botanists have recommended as best calculated to realize the end proposed, namely, a well-dried and sufficient specimen; we therefore content ourselves with giving a few brief directions upon the subject, such as appear to us of the most universal applicability; leaving it to the student himself to extend the scale of his operations by such increased means and apparatus as inclination and convenience may suggest.

Specimens should be gathered if possible on a dry day, since their beauty depends almost wholly upon the quickness with which they are dried. Most botanists, in their excursions, carry with them a tin box for the reception of their specimens. It should be about 15 or 18 inches in length, 6 inches in breadth, and about 3 inches deep; having a lid opening on the top nearly throughout its whole length, and secured by a catch. In such a box plants will remain fresh and unwithered for two or three days, if necessary; but where opportunity permits, the specimens should be transferred into the drying papers at the close of each day's excursion. We, however, prefer the use of the portfolio to the more ordinary tin case. The sides of the collecting folio should be of moderately stout binder's board, covered with strong muslin, the back and corners being of stout leather. The folio may be from 12 to 20 inches in length, and from 10 to 12 in breadth; and should contain about 50 leaves of thick unsized paper. It should be secured by strings, or, what is still better, straps and buckles, at each end and in the middle. A couple of loops should also be fixed to the cover, for the convenience of suspending the folio by a belt passing over the shoulder.

Instead of the tin box or portfolio, Dr. Short suggests the employment of a bag of India-rubber cloth, made like the ordinary travelling bag, except in being broader and less deep, so that the specimens may be introduced parallel with the mouth of the bag. This plan strikes us as well worthy of trial. A similar bag without the iron frame at the mouth, will be found extremely useful on a long botanical excursion, for enclosing several portfolios for more convenient carriage; whilst at the same time the specimens are effectually protected from the injurious effects of a shower of rain. A light covered basket of wicker-work, lined with India-rubber cloth, may be advantageously employed when the object is to collect a large quantity of specimens for the use of a class.

Arrived at home, the specimens are to be removed from the collecting folios, or whatever else may have been employed for the purpose, and committed to press in the following manner. The paper for drying should be about 20 inches by 15, and the dryers should consist of about 8 or 10 thicknesses of the paper, fastened together by a few stitches round the margin. Any unsized paper will answer for this purpose; smooth wrapping paper, or even old newspapers, being perhaps as good as any other. The number of dryers required will be of course in proportion to the activity of the collector; but if many specimens are to be preserved, 50 or 100 at least of these dryers should be in readiness for use. A few quires of thin blotting or tea paper of the same size as the dryers will also be necessary, and "With these fixtures you are prepared for the task before you, which consists in placing your plants in single sheets of paper, putting these sheets between alternate dryers, and subjecting the whole to pressure. This is the nicest part of the entire process, and as upon the mode in which it is done, the value and usefulness of your collection will depend, particular instructions will be given on this head. Take then any one plant from the box or folio, and lay it between the leaves of a single sheet of your paper, taking care to spread it out so as to have its parts as little confused as possible. In doing this, however, you must give to its parts no unnatural direction; for instance, do not give to a flower which naturally droops an erect position: flower stalks which are attached to but one side, must not be turned to both: a crooked or a tortuous stem must be left so, and a straight one must not be bent: in short, avoid all unnatural stiffness, formality, or artificial arrangement of its several parts, and preserve as nearly as possible the natural habit of the plant while growing—for as it is now dried it must for ever afterwards remain. This sheet, with the plant or plants so arranged in it, is then placed on one of the dryers, and another dryer laid on it.

"Of the smaller plants a number may be placed in one sheet; of the larger, several sheets may be required by the different parts of the same plant; but care must be particularly taken in arranging them, that the different plants thus placed in the same sheet do not overlay each other, lest under pressure they should adhere together, and otherwise interfere with the drying. In this manner you proceed, arranging your plants in single sheets and placing these between your dryers, until you have exhausted your box or folio, and formed a considerable pile. They are now ready for the press. Place the pile under your lever, screw, or weights; lay a thick board over it of the proper size, and begin the pressure, making it at first moderate, so that the plants may gradually yield to its influence without suffering violence or injury to their texture. In two or three hours the pressure may be increased, but not yet to the full amount of your power. After remaining in this situation for three or four hours longer, you will find, on examining them, that all the papers, both single sheets and thick dryers, have become quite wet with the moisture absorbed from the plants; and they should now be changed. This is done simply by shifting the single sheets, without opening them or disturbing the plants, into fresh dryers, and immediately placing them under the press again, which should now be made to bear somewhat more heavily on them. Your moist dryers are then to be spread out in the open air, and in hot sun-shine, (upon boards, or on a flat roof preferably,) until they are thoroughly dried. In this way you continue transferring your sheets with their contents from moist to fresh dryers, at first twice and afterwards once a day, increasing the pressure at each renewal until all moisture is extracted from them, and they are rendered flat and perfectly dry.

"The time required for this process will vary according to the nature and peculiarities of the plants acted on. As a general rule, and for the most of plants, three days will be sufficient; yet some, as most of the Grasses, are sufficiently dried in two days; others, more succulent and tenacious of life, as the *Sedums, &c.*, require as many weeks. These latter and some analogous plants even make efforts to grow for some days after being subjected to the influence of a powerful press; others in drying cast off their leaves, as the Fir tribe, &c., and some shed their flowers, as the *Agave Virginica.* To destroy this vegetating principle, and to dry such plants more speedily, and without a loss of their parts, it is advised to dip them in boiling water, and wipe them before they are placed in the sheet.

"In pressing at the same time a great variety of plants, it is always well to examine them once a day, and to remove from the parcel such as are sufficiently dried; continuing to act upon the remainder until all are finished. It is, however, by no means necessary that one parcel should be entirely disposed of before another is commenced with. On the contrary, you may have under press at the same time, plants in every stage of the drying process, only taking care that thin boards are interposed between the different parcels, to prevent the moisture of a fresh collection from affecting those which are dryer."*

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* *Instructions for the gathering and preservation of plants for Herbaria*, by C. W. Short, M. D., Lexington, Kentucky; whose specimens are greatly admired.

The press employed may be made after the manner of the common Cotton or Cheese-press, in miniature; or it may consist of two boards, drawn together by strong cords passing from the edges of the lower board to the projecting ends of an axle or roller crossing the upper one; and the pressure may be applied by means of a lever inserted into mortises in the middle of the axle, working like a capstan, the force being retained by a click and racket wheel. A most convenient and portable instrument of this kind was contrived by Dr. Riddell of Cincinnati, a notice of which is published in the Western Journal for July, 1834; and Dr. Locke has figured a modification of the same in Silliman's Journal for April, 1836.

It will be at once obvious that when out upon a long botanical tour, the convenience of the press and dryers cannot always be obtained; under such circumstances each botanist adopts the plan which when travelling he has found most convenient and expeditious. Prof. Lindley makes the following suggestions for the *travelling* botanist.

"In travelling, when conveniences of this kind cannot be had, and in wild uninhabited regions, it is better to have two or more pasteboards of the size of the paper in which your specimens are dried, and some stout cord or leathern straps. Having gathered specimens until you are apprehensive of their shrivelling, fill each sheet of paper with as many as it will contain; and having thus formed a good stout bundle, place it between the pasteboards, and compress it with your cord or straps. In the evening, or at the first convenient opportunity, unstrap the package, take a fresh sheet of paper, and make it very dry and hot before a fire; into the sheet, so heated, transfer the specimens in the first sheet of paper in your package; then dry that sheet, and shift into it the specimens lying in the second sheet; and so on, till all your specimens are shifted; then strap up the package anew, and repeat the operation at every convenient opportunity, until all the plants are dry. They should then be transferred to fresh paper, tied up rather loosely, and laid by."

It often happens, however, that new and interesting objects present themselves to the botanist when totally unprepared for making extensive collections. In such cases, very good specimens may be preserved between papers at the bottom of a trunk or portmanteau, being separated from the other contents by means of a thin piece of board or thick pasteboard. Indeed, a botanist will find great convenience in having such a false bottom to his ordinary portmanteau, where, by stowing away 2 or 3 quires of drying paper, he will be prepared in some degree for securing any thing of interest which may offer upon a journey not undertaken expressly for botanical purposes. If two or three pieces of binder's board be covered with coarse muslin, and well painted with varnish paint, they will effectually preserve the dried specimens from the moisture exhaled by those which are drying, and also prevent all dampness from reaching the contents of the box. If the papers be dried every night, specimens may in this way be very well preserved. If nothing better be at hand, plants may, when gathered, be rolled up between the folds of some old newspapers, and tied loosely round with a string. They will remain in this way for one, or even two or three days without withering so much but that they may be afterwards straightened and dried with tolerable success. These hints are given in consequence of the frequency with which we hear from our friends returned from a jaunt into perhaps a new and interesting part of the country, remarks respecting the beautiful plants they casually met with, mingled with regrets that they had no possible means of securing specimens for their botanical acquaintance. Now, if such well-disposed persons would only gather whatever struck them upon their journey as new and unusual; and convey them in the best manner which offered to their resting place, it would then be very easy to lay them between some double newspapers, and put their travelling trunk upon them for a weight; and in this way specimens of great interest to their botanical friends at home might be obtained at small cost of labor to themselves. Indeed, almost the only trouble would consist in drying the papers every night.

Curious fruits, not susceptible of pressure, may be well dried laying them in the sun; and they are afterwards to be kept in drawers with the cones of Firs, &c., which from their size and thickness cannot be otherwise preserved.

In collecting plants, a botanist should always bear in mind the probable wants of his friends and laborers in the same field of science. Thus not only will he have the high gratification of imparting what he knows will be joyfully received, and of contributing to the enlargement and diffusion of correct knowledge, in which all *true* naturalists have a common interest; but he will also by such means be certain of receiving, in exchange for his duplicates, the plants of those districts and countries which he might be unable to obtain by any other means; thus advancing his own attainments whilst promoting those of others.

A few words remain to be said on the arrangement and preservation of the specimens in the Herbarium. The great object to be effected by this collection being convenience in examination and comparison, every botanist is more or less guided by his own peculiar views in the disposition of his Herbarium. Some prefer cases for the ultimate reception of their specimens, and others folios, which again are made upon many different plans. We shall merely suggest a simple method, which every student may modify according to his own individual taste or convenience. To exhibit the specimens to good advantage, the paper employed should be white, or very nearly so, and of a good firm texture. Prof. Lindley observes that the best size for the paper appears by experience to be 10¾ inches, by 16½. He considers a larger size unnecessarily expensive, whilst it is certainly less convenient for use. Each species should occupy a separate half-sheet, and be fastened down to the paper with good strong glue, or by narrow pieces of gummed paper placed at intervals across the stems. The latter mode is preferred by some botanists on account of the ease with which a specimen may be removed if necessary, although it is much more tedious than the former. Many botanists leave their specimens loose upon the paper, which we, however, consider as exposing them to increased risk of injury. Each specimen should be accompanied by a label, indicating the name, principal synonyms, place of growth, and time of gathering, with any other particulars of interest. Where specimens are presented, the name of the donor should also appear upon the label. If the plants be fastened upon sized paper, these particulars may be written directly upon the foot of the sheet; but the original labels of correspondents should always be preserved, as they add materially to the value of the specimens. All the species of a genus should be enclosed within a whole sheet, bearing the name of the genus upon one of the lower corners outside. The genera of a family should follow each other in regular order, according to the arrangement of whatever author the student adopts as his guide. The families are then to be arranged in folios of the exact size of the papers (or about one-fourth of an inch larger all around). The backs of the folios should be of leather or cloth, strengthened by a piece of pasteboard, and should by no means exceed 2¼ inches in width; indeed an inch will be found, on the whole, the most convenient thickness. The folios may be secured by a central string, and some prefer having the ends also tied, which is no doubt essential when the specimens are not fixed down to the papers. The edges of the genus-papers should be turned inwards, by which means they will be better protected from dust. The backs of the folios should exhibit the names of the families (and also the genera when there are few,) contained in them upon a label, which may be fastened with paste or gum so as to be changeable at pleasure. The whole number of folios may then be arranged in an upright position, either on the shelves of a closet, an ordinary book-case of sufficient size, or in a cabinet expressly constructed for the purpose.

The Herbarium should always be kept in a perfectly dry room, and the closer and more exactly the doors of the closet or cabinet are fitted, the better is the chance of protecting the collection from the injurious depredations of insects.

Several modes have been tried for effectually protecting herbaria from the destructive ravages of one or two species of insects, to which dried specimens are particularly liable. The generally received opinion at present is, that lumps of camphor placed about the shelves, forms the most effectual preservative, care being taken to renew the material as fast as it evaporates. Spirits of turpentine suspended in one or two open vials may also be used with advantage. The saturation of specimens by a poisonous solution, as recommended by some botanists, is very tedious, and in our opinion needless, as well as on several accounts objectionable. After all the Herbarium of a diligent botanist will pass so frequently under his observation, that any very extensive ravages can hardly take place without his being aware of it in time to check the progress of the destroyers; nevertheless the precautions we have indicated ought in all cases to be adopted.

II. *A Catalogue of the Natural Orders of the Vegetable Kingdom, disposed (chiefly) according to the linear arrangement adopted by De Candolle.*[*]

CLASS I. FLOWERING PLANTS.

SUB-CLASS I.

EXOGENOUS OR DICOTYLEDONOUS PLANTS.

DIV. I. *Dichlamydeæ Thalamifloræ.*

Calyx of several sepals. Petals several, distinct, or rarely united, sometimes wanting; usually, as also the stamens, inserted upon the torus.

1. Ranunculaceæ. *The Crow-foot Tribe.*
†2. Dilleniaceæ. *The Dillenia Tribe.*
3. Wintereæ. *The Winter's-bark, or Star-anise Tribe.*
4. Magnoliaceæ. *The Magnolia Tribe.*
5. Anonaceæ. *The Custard-apple Tribe.*
6. Menispermaceæ. *The Cocculus Tribe.*

---

[*] The arrangement of the orders here presented, is substantially that given by De Candolle in his *Théorie Elémentaire*, and followed in his *Prodromus Syst. Veg.* as far as published; the principal changes being those adopted in the arrangement given by Mr. Arnott, in the seventh edition of the Encyclopœdia Britannica. The student should bear in mind, that, though the orders themselves are natural, their subordinate arrangement is artificial; it being obviously impossible to contrive an arrangement which shall express their several alliances. It is highly probable, as has been already observed, that the orders will at no distant period be grouped in a more natural manner; but as the arrangement of De Candolle is adopted in most botanical works, as well as in the Prodromus of that author, which will for a long time be the principal manual of botanists; and as it does not essentially differ from the arrangement of Jussieu, I have thought it proper to present it here in the form of a naked catalogue. To give the essential characters of the orders would far exceed the limits allowed to this subject.

7. Berberideæ. *The Barberry Tribe.*
8. Podophyllaceæ. *The Mandrake Tribe.*
9. Cabombaceæ. (*Ex.* Cabomba, Brasenia.)
10. Nymphæaceæ. *The Water-lily Tribe.*
Sub-order. 1. Nelumboneæ. (*Ex.* Nelumbium.)
" 2. Nymphaceæ. (*Ex.* Nymphæa.)
11. Sarraceniaceæ. *The Sarracenia Tribe.*
12. Papaveraceæ. *The Poppy Tribe.*
13. Fumariaceæ. *The Fumitory Tribe.*
14. Cruciferæ. *The Cruciferous Tribe.*
15. Capparideæ. *The Caper Tribe.*
‖16. Resedaceæ. *The Mignionette Tribe.*
†17. Flacourtiaceæ.
†18. Bixineæ. *The Arnatto Tribe.*
19. Cistineæ. *The Rock-rose Tribe.*
20. Violaceæ. *The Violet Tribe.*
21. Droseraceæ. *The Sundew Tribe.*
22. Polygaleæ. *The Polygala Tribe.*
†23. Tremandreæ.
†24. Tamariscineæ. *The Tamarisk Tribe.*
25. Frankeniaceæ. *The Frankenia Tribe.*
26. Elatineæ.
27. Caryophyllaceæ. *The Pink Tribe.*
28. Malvaceæ. *The Mallow Tribe.*
†29. Bombaceæ. *The Cotton-tree Tribe.*
†30. Byttneriaceæ. *The Chocolate Tribe.*
31. Tiliaceæ. *The Linden, or Bass-wood Tribe.*
†32. Dipterocarpeæ. *The Camphor-tree Tribe.*
†33. Chlenaceæ.
34. Ternstrœmiaceæ. *The Tea, or Camellia Tribe.*
†35. Olacineæ.
‖36. Aurantiaceæ. *The Orange Tribe.*
37. Hypericineæ. *The Hypericum, or St. John's-wort Tribe.*

†38. Reaumurieæ.
†39. Guttifereæ. *The Gamboge Tribe.*
†40. Marcgraviaceæ.
†41. Hippocrateaceæ.
†42. Erythoxyleæ.
†43. Malpighiaceæ. *The Barbadoes Cherry Tribe.*
44. Acerineæ. *The Maple Tribe.*
45. Hippocastaneæ. *The Horse-chestnut Tribe.*
†46. Rhizoboleæ.
†47. Sapindaceæ. *The Soap-tree Tribe.*
‖48. Meliaceæ. *The Pride-of-India Tribe.*
49. Cedrelaceæ. *The Mahogany Tribe.*
50. Ampelideæ. *The Vine Tribe.*
51. Lineæ. *The Flax Tribe.*
52. Geraniaceæ. *The Geranium Tribe.*
53. Balsamineæ. *The Balsam Tribe.*
‖54. Tropæoleæ. *The Nasturtium Tribe.*
55. Oxalideæ. *The Wood-sorrel Tribe.*
†56. Pittosporeæ. *The Pittosporum Tribe.*
†57. Brexiaceæ.
†58. Connaraceæ.
59. Zygophylleæ. *The Guaicum Tribe.*
‖60. Rutaceæ. *The Rue Tribe.*
‖61. Diosmeæ. *The Diosma, or Fraxinella Tribe.*
62. Lymnantheæ. *Ex.* Flœrkea.
63. Zanthoxylaceæ. *The Prickly-Ash Tribe.*
†64. Simaroubeæ. *The Quassia Tribe.*
†65. Ochnaceæ.
†66. Coriarieæ.

Div. II. *Dichlamydeæ Calycifloræ.*

Calyx composed of several sepals, more or less united at the base. Petals distinct or united, and, as also the stamens, adherent to the sepals; or rather springing from a thin expansion of the torus, which lines the bottom of the calyx.

§1. Epipetalæ.

†67. Stackhousieæ.
68. Celastrineæ. *The Celastrus Tribe.*
69. Staphylleaceæ. *The Bladder-nut Tribe.*
70. Rhamneæ. *The Buckthorn Tribe.*
71. Terebinthaceæ.
Sub-order 1. Anacardiaceæ. *The Sumach Tribe.*
† " 2. Spondiaceæ. *The Hog-plum Tribe.*
† " 3. Burseraceæ.
" 4. Amyrideæ.
72. Leguminosæ. *The Pea Tribe.*
†73. Moringeæ.
74. Rosaceæ.
Sub-order 1. Chrysobalaneæ. *The Cocoa-plum Tribe.*
" 2. Amygdaleæ. *The Almond Tribe.*
" 3. Spiræeæ. *The Spiræa Tribe.*
" 4. Sanguisorbeæ. *The Burnet Tribe.*
" 5. Potentilleæ. *The Potentilla, or Strawberry Tribe.*
" 6. Roseæ. *The Rose Tribe.*
" 7. Pomaceæ. *The Apple and Pear Tribe.*
75. Calycantheæ. *The Carolina-allspice Tribe.*
76. Salicarieæ. *The Lythrum Tribe.*
77. Ceratophyllaceæ. *The Hornwort Tribe.*

78. Rhizophoreæ. *The Mangrove Tribe.*
†79. Vochysiaceæ.
†80. Combretaceæ.
†81. Memecyleæ.
82. Melastomaceæ. *Ex.* Rhexia.
†83. Alangieæ.
84. Philadelphieæ. *The Syringa Tribe.*
†85. Myrtaceæ. *The Myrtle Tribe.*
86. Onagrariæ. *The Evening Primrose Tribe.*
87. Halorageæ. *The Water-milfoil Tribe.*
88. Loaseæ. *Ex.* Bartonia, *Pursh.*
89. Cucurbitaceæ. *The Gourd, or Cucumber Tribe.*
90. Papayaceæ. *The Papaw Tribe.*
†91. Belvisiaceæ.
92. Passifloreæ. *The Passion-flower Tribe.*
93. Turneraceæ. *Ex.* Turnera.
†94. Fourquieriaceæ.
95. Portulaceæ. *The Purslane Tribe.*
96. Paronychiaceæ. *Ex.* Anychia, Spergula.
97. Crassulaceæ. *The House-leek Tribe.*
98. Ficoideæ. *Ex.* The Ice-plant.
† 99. Nitrariaceæ.
†100. Surianeæ. *Ex.* Suriana.
101. Cacteæ. *The Prickly-pear, or Cactus Tribe.*
102. Grossularieæ. *The Currant Tribe.*
103. Galacineæ. *Ex.* Galax.
104. Saxifragaceæ. *The Saxifrage Tribe.*
†105. Bruniaceæ.
106. Hamamelideæ. *The Wych-Hazel Tribe.*

§ 2. Epipetalæ.

107. Umbelliferæ. *The Umbelliferous Tribe.*
108. Araliaceæ. *The Aralia, or Ginseng Tribe.*
109. Corneæ. *The Dogwood Tribe.*

§ 3. Epicorollæ.

110. Loranthaceæ. *The Misletoe Tribe.*
111. Caprifoliaceæ. *The Honeysuckle Tribe.*
112. Rubiaceæ. *The Madder (and Peruvian bark) Tribe.*
113. Valerianeæ. *The Valerian Tribe.*
114. Dipsaceæ. *The Scabious Tribe.*
†115. Calycereæ.
†116. Globularineæ.
117. Compositæ. *The Sunflower Tribe.*

§ 4. Pericorollæ.

†118. Brunoniaceæ.
†119. Goodenoviæ.
†120. Stylidieæ.
121. Lobeliaceæ. *The Lobelia Tribe.*
122. Campanulaceæ. *The Bell-flower Tribe.*
†123. Gesneriaceæ.
124. Ericineæ. *The Heath Tribe.*
    Sub-order 1. Ericeæ. *The Heath Tribe proper.*
    " 2. Vaccinieæ. *The Whortleberry Tribe.*
    " 3. Monotropeæ. *Ex.* Monotropa, Pyrola.
†125. Epacrideæ.
†126. Columelliaceæ.
127. Styraceæ. *The Styrax Tribe.*

Div. III. *Dichlamydeæ Corollifloræ.*

Petals united into a monopetalous hypogynous corolla (not adherent with the calyx).

128. Ebenaceæ. *The Ebony Tribe.*
129. Ilicineæ. *The Holly Tribe.*

130. Sapoteæ. *Ex.* Bumelia.
†131. Myrsineæ.
‖132. Jasmineæ. *The Jasmine Tribe.*
133. Oleaceæ. *The Olive Tribe.*
134. Asclepiadeæ. *The Milk-weed Tribe.*
135. Apocyneæ. *The Dogbane Tribe.*
†136. Loganiaceæ.
†137. Potaliaceæ.
138. Spigeliaceæ. *The Pink-root Tribe.*
139. Gentianeæ. *The Gentian Tribe.*
140. Bignoniaceæ. *The Bignonia Tribe.*
‖141. Cobæaceæ. *Ex.* Cobæa.
142. Polemoniaceæ. *The Polemonium Tribe.*
143. Hydroleaceæ. *Ex.* Hydrolea, Diapensia.
144. Convolvulaceæ. *The Morning-glory Tribe.*
†145. Cordiaceæ. *The Cordia Tribe.*
146. Boragineæ. *The Borage Tribe.*
147. Hydrophyllaceæ. *The Waterleaf Tribe.*
148. Solaneæ. *The Nightshade Tribe.*
149. Scrophularineæ. *The Scrophularia Tribe.*
150. Orobancheæ. *The Beech-drop Tribe.*
151. Verbenaceæ. *The Vervain Tribe.*
152. Myoporineæ.
†153. Selagineæ.
154. Labiatæ. *The Mint Tribe.*
155. Acanthaceæ. *The Justicia Tribe.*
156. Lentibulariæ. *The Utricularia Tribe.*
157. Primulaceæ. *The Primrose Tribe.*
158. Plumbagineæ. *The Marsh-Rosemary Tribe.*
159. Plantagineæ. *The Plantain Tribe.*
160. Nyctagineæ. *The Mirabilis Tribe.*
161. Amaranthaceæ. *The Amaranth Tribe.*

DIV. IV. *Monochlamydeæ.*

Floral envelopes single; the corolla wanting or confounded with the calyx.

162. Chenopodeæ. *The Pigweed Tribe.*
163. Phytolacceæ. *The Poke Tribe.*
164. Polygoneæ. *The Buckwheat Tribe.*
†165. Begoniaceæ. *Ex.* Begonia.
166. Laurineæ. *The Laurel Tribe.*
†167. Hernandiaceæ.
†168. Myristiceæ. *The Nutmeg Tribe.*
†169. Proteaceæ. *The Protæa Tribe.*
170. Elæagneæ. *The Oleaster Tribe.*
†171. Penæaceæ.
172. Thymeleæ. *The Daphne, or Lace-bark Tribe.*
†173. Aquilarineæ.
†174. Chailletiaceæ.
†175. Samydeæ.
†176. Homalineæ.
177. Santalaceæ. *The Sanders-wood Tribe.*
178. Aristolochieæ. *The Birthwort Tribe.*
†179. Cytineæ.
Sub-order. 1. Rhizantheæ. *Ex.* Rafflesia.
" 2. Nepentheæ. *Ex.* Nepenthes, the East Indian Pitcher-Plant.
180. Datisceæ.
181. Empetreæ. *The Empetrum Tribe.*
182. Euphorbiaceæ. *The Euphorbia Tribe.*
183. Urticaceæ. *The Nettle Tribe.*
184. Ulmaceæ. *The Elm Tribe.*
185. Artocarpeæ. *The Bread-fruit Tribe.*
†186. Monimieæ.
†187. Atherospermeæ.

†188. Lacistemeæ.
†189. Chlorantheæ.
190. Piperaceæ. *The Pepper Tribe.*
191. Podostemeæ. *Ex.* Podostemum, *Michx.*
192. Saurureæ. *Ex.* Saururus, or *Lizard's-Tail.*
193. Amentaceæ.
  Sub-order 1. Salicineæ. *The Willow Tribe.*
  " 2. Myriceæ. *The Bayberry Tribe.*
  " 3. Betulineæ. *The Birch Tribe.*
  " 4. Plataneæ. *The Button-wood Tribe.*
  " 5, Cupuliferæ. *The Oak Tribe.*
†194. Stilagineæ.
195. Juglandeæ. *The Walnut Tribe.*
196. Coniferæ. *The Fir Tribe.*
197. Cycadeæ. *The Cycas, or Sago Tribe.*

SUB-CLASS II.

ENDOGENOUS OR MONOCOTYLEDONOUS PLANTS.

Div. I. *Petaloideæ.*

198. Hydrocharideæ. *The Frog-bit Tribe.*
†199. Balanophoreæ.
200. Orchideæ. *The Orchis Tribe.*
†201. Scitamineæ. *The Ginger Tribe.*
202. Marantaceæ. *The Arrow-root Tribe.*
†203. Musaceæ. *The Banana Tribe.*
204. Irideæ. *The Iris Tribe.*
205. Burmanniæ. *Ex.* Burmannia.
206. Hæmodoraceæ. *The Red-root Tribe.*
207. Amaryllideæ. *The Narcissus Tribe.*
208. Hypoxideæ. *The Hypoxis Tribe.*
†209. Barbaceniеæ.
210. Dioscorineæ. *The Disocorea Tribe.*

211. Smilaceæ. *The Green-briar Tribe.*
212. Bromeliaceæ. *The Pine-Apple Tribe.*
213. Asphodeleæ. *The Hyacinth Tribe.*
†214. Gilliesieæ. *The Gilliesia Tribe.*
215. Palmæ. *The Palm Tribe.*
216. Liliaceæ. *The Lily Tribe.*
217. Melanthaceæ. *The Colchicum Tribe.*
218. Pontederiaceæ. *The Pontederia Tribe.*
219. Commelineæ. *The Commelina Tribe.*
220. Alismaceæ. *The Water-plantain Tribe.*
221. Juncagineæ. *Ex.* Scheuchzeria.
†222. Pandaneæ. *The Screw-pine Tribe.*
223. Aroideæ. *The Arum Tribe.*
224. Pistiaceæ. *The Duck-weed Tribe.*
225. Typhaceæ. *The Cat-tail Tribe.*
226. Fluviales. *The Pond-weed Tribe.*
227. Restiaceæ. *Ex.* Eriocaulon.
228. Xyrideæ. *The Xyris Tribe.*
229. Junceæ. *The Juncus Tribe.*

Div. II. *Glumaceæ.*

230. Cyperaceæ. *The Sedge-grass Tribe.*
231. Gramineæ. *The Grass Tribe.*

CLASS II. FLOWERLESS PLANTS.

SUB-CLASS I.

FIBRO-VASCULAR FLOWERLESS PLANTS.

232. Equisetaceæ. *The Equisetum Tribe.*
233. Filices. *The Ferns.*
234. Marsileaceæ.
235. Lycopodiaceæ. *The Club-moss Tribe.*

SUB-CLASS II.

CELLULAR FLOWERLESS PLANTS.

236. Musci. *The Mosses.*
237. Hepaticæ. *The Liverworts.*
238. Characeæ. *The Chara Tribe.*
239. Lichenes. *The Lichen Tribe.*
240. Fungi. *The Mushroom Tribe.*
241. Algæ. *The Sea-weeds.*

Obs. The orders in our enumeration distinguished by the sign (†) are wholly exotic, no plants belonging to them being natives of North America; the Mexican dominions, of course, being excluded. The orders thus designated (‖) are also exotic, but have well-known representatives in our gardens. The remaining families comprise all the indigenous plants of this country, so far as is now known.

Our plants, however, are by no means equally divided between these orders; the number of species having nothing to do with the distinctness of a family. Thus, we find by consulting Prof. Torrey's catalogue of the Orders and Genera of North American plants, appended to the American edition of Lindley's Introduction to the Natural System, (which being the latest enumeration we adopt as the basis of these remarks,) that of about 160 orders among which North American plants are divided, 17, viz: Cedreleæ, Cycadeæ, Datisceæ, Dipsaceæ, Ebenaceæ, Elatineæ, Galacineæ, Myoporineæ, Papayaceæ, Piperaceæ, Podostemeæ, Rhizophoreæ, Saurureæ, Spigeliaceæ, Staphyleaceæ, Thymeleæ, and Turneraceæ, include each but a single indigenous species; and 24 additional orders comprise severally 2, 3, and 4 species. It appears, therefore, that although our country furnishes examples of two-thirds of the known families of plants, yet the greatest part of them are included in comparatively few orders. The whole number of North American plants, as enumerated 5 years since in the catalogue just referred to, is 8,334, of which 4,273 are Flowerless Plants. This estimate, doubtless, falls much below the true number, which, according to a calculation founded on the increase of several families that have recently undergone a careful revision, is about 5,000. The present ratio will, however, be very slightly if at all affected by the increase. To give a view of the families to which our vegetation principally belongs, and in which, therefore, the student is more especially interested, we subjoin the following list, the number of species as determined in 1831 being annexed to the name of each family.

Compositæ,	566	Polygoneæ,	47
Gramineæ,	330	Gentianeæ,	44
Cyperaceæ,	250	Asclepiadeæ,	43
Leguminosæ,	236	Rubiaceæ,	39
Rosaceæ,	158	Polemoniaceæ,	38
Cruciferæ,	136	Boragineæ,	35
Scrophularineæ,	131	Violaceæ,	35
Amentaceæ,	120	Convolvulaceæ,	35
Labiatæ,	108	Solaneæ,	34
Ericineæ,	108	Primulaceæ,	31
Ranunculaceæ,	107	Coniferæ,	31
Umbelliferæ,	69	Chenopodeæ,	31
Onagrariæ,	69	Liliaceæ,	29
Saxifragaceæ,	67	Malvaceæ	28
Orchideæ,	62	Junceæ	24
Caryophyllaceæ,	57	Melanthaceæ,	24
Caprifoliaceæ,	53	Polygaleæ	23
Euphorbiaceæ,	52		

Total amount of species in 35 Orders, 3,250

It appears, therefore, that the 35 orders here enumerated comprise thirteen sixteenths of the North American plants; and of these, moreover, the 9 families at the head of the list include one-half of the whole number. No inconsiderable knowledge of North American botany, therefore, may be gained by a thorough acquaintance with a very small number of families.

ERRATA.

Page 31, line 18 from bottom, for tubiferous, *read* tube*ri*ferous.

“ 69, last line, for contain*ih*g, *read* containi*n*g.

“ 133, note, for st*r*yraciflua, *read* styraciflua.

“ 180, line 1, for I*o*nardia, *read* Isnardia.

“ 217, line 16 from bottom, after *endocarp*, *insert* “and the intermediate portion the *mesocarp*.”

“ 324, note, line 10, (in some copies) for “the ovary *is*,” *read* “the ovary *if*.”

“ 227, line 3 from bottom, for SPHALEROCARPUM, *read* SPHALEROCARPIUM.

“ 228, note, line 3 from bottom, (in some copies) for “flesh, fruit,” *read* flesh*y* fruit.

“ 250, note, last line, (in some copies) for “which burst through coleorhiza,” *read* which *has* burst through *the* coleorhiza.

“ 255, line 11 from bottom, for Marsil*i*aceæ, *read* Marsil*e*aceæ.

“ 265, for MARSILIACEÆ, *read* MARSILEACEÆ.

“ 274, last line, (in some copies) for V*ulgaris*, *read* v*ulgaris*.

“ 276, first line, for *Lichenes*, *read Lichens*.

“ 316, line 14 from bottom, for pinnatified, *read* pinnatifid.

“ 333, line 20 from top, for *Monochlamydæ*, *read* *Monochlamyde*æ.

“ 368, line 11 from bottom, for E*ridentate*, *read* T*ridentate*.

INDEX.

Abnormal, 365.
Acaulescent, 33.
Accumbent, 243.
Acerose, 366.
Achenium, 223, 225.
Acicular, 366.
Acinaciformis, 364.
Acuminate, 369.
Acute, 368.
Adnate,
Agamous plants, 252.
Aged trees, 50.
Æstivation, 176.
Æterio, 223.
Air-cells, 15.
Alate, 364.
Alburnum, 48, 239.
Algæ, 282.
Alternate, 96.
Alveolate, 375.
Ament, 169.
Amphisarca, 225.
Amplexicaul, 388.
Anamorphosis, 75.
Anatropous, 203, 237.
Aneipital, 363.
Angled 370.
Annual, 380.
Annulus, 261, 280.
Anther, 190, 152.
Anthodium, 172, 183.
Apetalous, 184.
Apiculate, 369.
Apocarpous, 197.
Apophysis, 270.
Apothecium, 277.
Arachnoid, 377.
Argol, 278.
Arillus, or aril, 235.
Aristate, 369.
Arrow-shaped, 86, 367.
Articulate, 373.
Artificial systems, 293.
    "   classes, 294.
    "   orders, 289.
Ascending, 385.
Aspergilliform, 196.
Attenuate, 368.
Auriculate, 367.
Awl-shaped, 366.
Awn, 158.
Awned, 369.
Axe-shaped, 364.
Axil, 76.
Axillary, 389.

Bacca, 227.
Balausta, 227.
Balsams. 133.
Banded,
Barbs 24.
Bark, 43.
Basal, 389.
Bearded, 377.
Bell-shaped, 182, 364.
Berry, 231.
Biennial, 380.
Bifarious, 391.
Bifoliolate, 375.
Bijugate, 374.
Bilabiate, 364.
Bipinnate, 89, 374.
Bipinnately cleft, &c. 3
Black, 382.
Bladdery, 365.
Bony, 379.
Bordered, 384.
Brachiate, 387.
Bracts, 154.
Bracteoles, 154.

Branched, 373.
Breathing-pores, 20.
Bristles, 24.
Brsitle-pointed, 369.
Bristle-shaped, 366.
Brown, 382.
Bryophyllum, 69.
Buds, 65.
  “ adventitious, 69.
Bulb, 38, 69.

Caducous, 381.
Cæspitose, 391.
Calyptra, 268.
Calyx, 177, 152.
  “ bilabiate, 178.
  “ gamosepalous, 178.
  “ inferior, 179.
  “ polysepalous, 178.
  “ superior, 179.
Campanulate, 182, 364.
Campulitropous, 204, 237.
Canaliculate, 363.
Canescent, 377, 382.
Capillary, 363.
Capitate, 368.
Capitulum, 172.
Capsule, 225, 230.
Carcerulus, 224.
Carina, 183.
Carinate, 363.
Cartilaginous, 379,
Caruncle, 235.
Catkin, 169.
Caudate, 369.
Caulescent, 33.
Cauline, 96, 389.
Caulocarpous, 380.
Caryopsis, 224, 228.
Cellular integument, 44.
Cellular Flowerless plants, 255, 330.
Cellular tissue, 2.
Ceratium, 225.
Cernuus, 386.
Chaffy, 277.
Chalaza, 203, 236.
Channelled, 363.
Characeæ, 274.
Chartaceous, 379.
Chestnut-brown, 382.
Chromule, 6, 128.
Cirrhous, 369.
Classes, 288. 292.
Classification, 286.
Claw, 181.
Clasping, 388.
Cleft, 199, 371.
Climbers, 34.
Climbing, 386.
Clouded, 384.
Club-mosses, 264.
Ciliæ, 269.
Ciliate, 377.
Circinate, 386.
Cobwebby, 377.
Collet, 27.
Colored, 381.
Coloring principles, 137.
Columella, 219, 270.
Coma, 238, 246.
Compound, 373.
Compressed, 363.
Conceptaculum, 224.
Conical, 362.
Coniferous wood, 9, 46.
Conjugately pinnate, 174.
Connate, 388.
Connectivum, 191.
Connivent, 387.
Conoidal, 362.
Contorted, 177.
Convolute, 386.
Cordate, 86, 367.
Coriaceous, 379.
Corky, 379.
Corolla, 180.
Cormus, 37.
Corona, 184.
Cortical integument, 44.
Corymb, 171.
Cotyledons, 241.
Cremocarpium, 227, 228.
Crenate, 84, 370.
Crested, 364.
Cristate, 364.
Crustaceous, 379.
Cryptogamous plants, 252.
Cucullate, 365.
Culm, 34.

Cuneate, 366.
Cuneiform, 366.
Cup-shaped, 365.
Cupule, 156.
Curve-veined, 82.
Cuspidate, 369.
Cuticle, 18.
Cyathiform, 365.
Cylindraceous, 362.
Cylindrical, 362.
Cyme, 173.
Cynarrhodum, 224.
Cypsela, 226.

Deciduous, 99, 381.
Declined, 386.
Decompound, 89, 373.
Decumbent, 387.
Decurrent, 388.
Decussate, 391.
Dehiscent, 218.
Deltoid, 367.
Dentate, 370.
Denticulate, 370.
Depauperate, 391.
Depressed, 336.
Descending, 385.
Dolabriformis, 364.
Diadelphous, 189.
Diclesium, 227.
Dichotomous, 373.
Dicotyledonous, 241.
Didynamous, 189.
Diffuse, 387.
Digitate, 87, 372.
Digitately pinnate, 374.
Dimidiate, 269, 368.
Diplotegia, 227.
Disk, 201.
Disk-florets, 183.
Dissepiments, 197.
Divided, 371.
Divaricate, 387.
Dorsal, 389.
Dotted, 384.
Drupe, 223, 228.
Ducts, 12.
Dull, 378.
Dwarf, 379.

Echinate, 376.
Elaiodine, 134.
Elasticity, 104.
Elaters, 272.
Elementary Organs, 1.
Ell, 380.
Elliptical, 366.
Emarginate, 368.
Embryo, 240.
Emersed, 387.
Endocarp, 217.
Endogenous plants, 40, 329.
Endogenous structure, 51.
Endorhizæ, 250.
Endosmosis, 106.
Endosperm, 239.
Ensiform, 366.
Entire, 368.
Epicarp, 217.
Epigæous,
Epigynous, 188.
Epiphyllous, 389.
Epiphytic, 382.
Episperm, 239.
Equisetaceæ, 256.
Equilateral, 368.
Erect, 385.
Erose, 370.
Ergot, 280.
Evaporation, 116.
Even, 376.
Evergreens, 99.
Excitability, 107.
Excretions, 129.
Exembryonateæ, 253.
Exogenous plants, 40, 238.
Exogenous structure, 40.
Exorhizæ, 250.
Extensibility, 104.

Falcate, 367.
Fan-shaped, 364.
Farinaceous, 239.
Farinose, 377.
Fascicle, 173.
Fascicled, 99.
Fastigiate, 391.
Favose, 375.
Feather-veined, 79.
Fecula, 124.
Ferns, 259.
Fertilization, 204.

Flabelliform, 364.
Fibrous, 379.
Fibrous cellular tissue, 4.
Fibro-membranous cellular tissue, 4.
Fibro-vascular Flowerless plants, 255, 330.
Filices, 259.
Filament, 152, 186.
Filiform, 362.
Fimbriate, 378.
Fissus, 371,
Fistulous, 363.
Flexuose, 386.
Floating, 387.
Floral, 96.
Floral Envelopes, 176.
Flower, 151.
“ achlamydeous, 154.
“ complete, 154.
“ diclinous, 153.
“ diœcious, 154.
monœcious, 154.
naked, 154.
nature of, 158.
perfect, 153.
pistillate, 153.
separated, 153.
staminate, 153.
Flowering plants, 328.
Flowerless plants, 252, 330.
Foliole, 77, 87.
Follicle, 223.
Food of plants, 108, 110.
Foot-stalk, 76.
Foramen, 202.
Fork-veined, 78.
Fugacious, 99, 381.
Fuliginose, 382.
Fumitory tribe, 38.
Fungi, 279.
Funiculus, 201.
Funnel-shaped, 364.
Furcate, 373.
Furrowed, 375.
Fuscous, 382.
Fusiform, 30, 362.
Free, 388.
Fringed, 378.
Frond, 277, 282.
Fruits, 223.
Fruits, aggregate, 229.
“ compound, 230.
“ collective, 232.
“ pseudospermic, 227.
“ simple, 223.

Galea, 182.
Geminate, 391.
Cenera, 288, 291.
Geniculate, 386.
Germen, 195.
Germination, 248.
Gibbous, 363.
Glabrous, 378.
Gladiate, 366.
Glandular, 378.
Glandular hairs, 25.
Glandulose, 378.
Glans, 226.
Glaucescent,
Glaucous, 379.
Globose, 362.
Globuline, 6.
Glomerate, 391.
Glomerule, 173.
Glumes, 157.
Glossology, 360.
Gourd tribe, 3.
Gray, 382.
Gum, 123.
Gynandrous, 188.
Gyrate, 386.

Hairs, 22.
Hairy, 376.
Halbert-shaped, 86.
Hastate, 86, 367.
Head, 172.
Heart-shaped, 86, 36
Heart-wood, 48.
Helmet, 182.
Hepaticæ, 272.
Hepatic Mosses, 272.
Herbaceous, 34, 379.
Hesperidium, 226, 231.
Heterotropous, 204.
Hidden-veined, 86.
Hilum, 204, 234.
Hirsute, 376.
Hoary, 382.
Hooded, 365.

Horizontal, 385.
Horny, 379.
Horse-tails, 256.
House-leek, 20.
Hybrids, 290.
Hygroscopicity, 105.
Hymenium, 279.
Hypocrateriform, 182. 364,
Hypogæous, 389.
Hypogonous, 187, 37.
Hysteranthous, 380.

Imbricated, 177.
Incanus, 377.
Incised, 371.
Inclined, 386.
Incumbent, 243.
Incurved, 386.
Indehiscent, 218.
Individuals, 288.
Inequilateral, 92, 368.
Inflated, 365.
Inflexed, 386.
Inflorescence, 169.
Infundibuliform, 182, 364.
Innate, 388.
Integer, 370.
Integerrimus, 369.
Intercellular passages, 14.
Internode, 33.
Interrupted, 391.
Involucel, 156.
Involucre, 156.
Irregular, 365.
Irritability, 107.

Jelly, 124.
Juice, descending, 121.
  " milky, 131.
  " nourishing, 122.
  " proper, 129.
  " resinous, 132.

Keel, 183.
Keeled, 363.
Kidney-shaped, 367.
Knobby, 364.

Labiate, 182, 364.
Laciniate, 371.
Lacunose, 375.
Lævigatus, 378.
Lamina, 76.
Lanate, 377.
Lanceolate, 366.
Lanuginose, 377.
Leaf-buds, 65.
Leaflet, 77, 87.
Leaf-stalk, 76, 90.
Leaves, 72.
Leathery, 379.
Legume, 223, 224.
Lenticels, 26.
Lenticular, 262.
Lepidote, 377.
Leprous, 377.
Liber, 44.
Lichenes, or Lichens, 276.
Lid, 269.
Lignin, 126.
Ligulate, 185, 366.
Limb, 76.
Linear, 79, 366.
Linguiformis, 364.
Linnæan classification, 293.
Liverworts, 272.
Lobed, 74, 371.
Loculicidal, 220.
Lodicula, 158.
Loment, 223, 225.
Lomentaceous, 90.
Lorate, 366.
Lucidus, 378.
Lurid, 382.
Lycopodiaceæ, 264.
Lyrate, 370.

Marbled,
Marcescent, 381.
Marginal, 389.
Margined, 384.
Marsileaceæ, 265.
Medulla, 42.
Medulle, 6.
Medullary rays, 43.
Medullary sheath, 38.
Membranaceous, 379.
Mesocarp, 217.
Micropyle, 236.
Midrib, 74.
Mitriform, 269.
Monadelphous, 188.

Moniliform, 364.
Monocarpous, 380.
Monocotyledonous, 241.
Monopetalous, 181.
Mosses, 266.
Mucous, 379.
Mucronate, 369.
Multijugate, 374.
Muricate, 376.
Muriform cellular tissue, 4.
Musci, 266.
Mushrooms, 279.
Muticus, 369.

Naked, 378.
Napiform, 30, 362.
Natural orders, 293.
" catalogue of, 407.
Natural system, 311.
Neck, 27.
Nectary, 158.
Needle-shaped, 366.
Nerves, 74.
Netted, 375.
Netted-veined, 78.
Neutral principles, 136.
Nitidus, 378.
Node, 33.
Nomenclature, 355.
Normal, 365.
Nucleus, 202.
Nuculanium, 226.
Nutant, 386.
Nutrition, 103.
Nut, 229.

Obcordate, 368.
Oblique, 92, 368.
Oblong, 366.
Obovate, 80.
Obtuse, 368.
Ocellated, 385.
Ochreæ, 101.
Offset, 35.
Oils, fixed, 134.
" volatile, 133.
Oleine, 134.
Operculum, 269.
Opposite, 96.
Orbicular, 366.
Orders, 288, 292.
Organs of Vegetation, 16.
" compound, 17.
" external, 17.
" fundamental, 18.
" of nutrition, 18.
" of Reproduction, 151.
Orthotropous, 203, 237.
Oval, 366.
Ovary, 152, 195.
Ovate, 80.
Ovoidal, 362.
Ovules, 201.

Painted,
Palaceous, 377.
Palate, 182.
Paleæ, 158.
Palmate, 31, 371.
Palmately cleft, &c., 372.
Palmatisectus, &c., 372.
Palminerved, 81.
Pandurate, 368.
Panduriform, 368.
Panicle, 170.
Papery, 379.
Pappillose, 376.
Pappus, 180.
Parallel-veined, 78, 79.
Parasitic, 72.
Parenchyma, 4, 75.
Partitus, 371.
Parted, 83, 371.
Pectinate, 372.
Pedate, 372.
Pedicel, 154, 169.
Peduncle, 154, 169.
Pellucid-punctate, 134.
Peltate, 82.
Peltinerved, 82.
Pepo, 227, 231.
Perennial, 380.
Perfoliate, 94.
Pericarp, 212.
Perichæth, 268.
Periclinium, 156.
Peridium, 280.
Perigynium, 156.
Perigynous, 188.
Perisperm, 239.
Peristome, 269.
Persistent, 99, 381.

Personate, 182, 364.
Perspiration, 117.
Petals, 152, 180.
Petiole, 76, 90.
Petiolules, 92.
Phyllodium, 92.
Placenta, 196.
" central, 199.
" parietal, 198.
Plane, 363.
Plumbeous, 382.
Plumose, 196, 378.
Plumule, 241.
Pileus, 279.
Pilose, 376.
Pinnate, 87, 373, 274.
Pinnately cleft, &c., 372.
Pinnatifid, 372.
Pinnatisectus, &c., 372.
Pistil, 152. 193.
Pith, 42.
Pitcher-shaped, 365.
Pitted, 375.
Podetia, 277.
Podosperm, 20.
Pointless, 369.
Poisons, effects on plants, 148.
Pollen, 192.
Polyadelphous, 189.
Polycarpous, 380.
Polypetalous, 180.
Pome, 230, 227.
Præfloration, 176.
Præfoliation, 70.
Præmorse, 368.
Prickles, 26
Prickly, 376.
Primine, 202.
Primordial, 96.
Principles of Classification, 286.
Prismatic, 363.
Procumbent, 387.
Properties of tissue, 104.
Prostrate, 387.
Proteranthous, 380.
Pubescent, 376.
Pulverulent, 377
Pulvinate, 364.
Pumilus, 379.
Pungent, 369.
Pusillus, 380.
Pygmæus, 379.
Pyramidal, 362.
Pyriform, 362.
Pyxidium, 221, 224, 230.

Quadrilateral, 363.
Quinquefoliolate, 375.

Raceme, 170.
Rachis, 169.
Radiate, 391.
Radiated-veined, 81.
Radical, 96.
Radicle, 241.
Rameal, 96.
Ramose, 373.
Raphe, 204, 237.
Ray-florets, 184.
Receptacle, 201.
Recurved, 386.
Reflexed, 386.
Regma, 224.
Regular, 365.
Repand, 370.
Repent, 387.
Reniform, 367.
Resin-like principles, 136.
Respiration, 118.
Resupinate, 385.
Reticulated, 78, 375.
Retrorse, 387.
Retuse, 368.
Revolute, 386.
Rhizocarpous, 380.
Rhizoma, 35.
Rhomboid, 367.
Ribs, 74.
Ringent, 182, 364.
Root, 26.
Root-stock, 35.
Rostellate, 369.
Rostrate, 369.
Rosulate, 390.
Rotate, 182, 364.
Rotundus, 366.
Rounded, 368.
Roundish, 366.
Rufous, 382.
Ruminated, 239.
Runcinate, 370.
Runner, 35.

Sabre-shaped, 364.
Sagittate, 85, 367.
Salver-shaped, 182, 364.
Samara, 214, 229.
Sap, ascending, 113.
" elaborated, 121.
Sap-wood, 48.
Sarcocarp, 217.
Scabrous, 376.
Scaly, 377.
Scandent, 386.
Scape, 175.
Scarious, 379.
Scarred, 375.
Scouring-rush, 256.
Scrobiculate, 375.
Scurfy, 377.
Scutellum, 277.
Scypha, 277.
Sea-weeds, 282.
Secretions, 130.
Sectus, 371.
Secund, 386.
Secundine, 202.
Seed, 233.
" naked, 234.
Seed-vessel, 212.
Sensible movements, 147.
Sensitive plant, 107.
Sepals, 152.
Septicidal, 219.
Septifragal, 220.
Sericeous, 377.
Serrate, 370.
Serrulate, 370.
Sessile, 388.
Seta, 158, 268.
Setaceous, 366.
Setose, 369.
Sheathing, 91.
Sheaths, 91.
Shining, 378.
Signs, 394.
Silicule, 225, 231.
Silique, 225, 231.
Silky, 377.
Simple, 373.
Sinuate, 370.
Silvery, 381.
Sleep of plants, 144.
Smooth, 378.
Smut, 280.
Solitary, 392.
Soredia, 277.
Sorosis, 228, 233.
Spadix, 169.
Span, 380.
Spathe, 155.
Spatulate, 366.
Special directions of organs, 137.
" of root and stem, 138, 143.
" of leaves, 143.
Species, 288.
Spermoderm, 239.
Sphalerocarpium, 227.
Spheroidal, 362.
Spike, 169.
Spikelet, 157.
Spindle-shaped, 30, 362.
Spines, 69.
Spinose, 376.
Spiral, 391.
Spiral-vessels, 10.
Spongelets, 29.
Spongioles, 29.
Spongy, 379.
Sporidia, 282.
Sporules, or spores, 253.
Spotted, 384.
Spreading, 387.
Spur, 184.
Squamose, 377.
Squamulæ, 158.
Squarrose, 391.
Stamens, 152, 186.
Standard, 183.
Starch, 124.
Stearine, 134.
Stearoptine, 134.
Stellate, 373.
Stem, 33.
Stigma, 195, 152.
Stinging, 378.
Stipe, 196, 260, 279.
Stipules, 100.
Stings, 25.
Stipitate, 388.
Stipulules, 102.
Stolon, 35.
Stoma, 269.

Stomata, 20.
Straight, 385.
Straight-veined, 82.
Strap-shaped, 366.
Striate, 375.
Strict, 385.
Strigose, 376.
Striped, 384.
Strobile, 228, 232.
Strophiole, 235.
Style, 152, 195.
Sub-classes, 293.
Suberose, 379.
Sub-genera, 292.
Sub-mersed, 387.
Sub-orders, 293.
Subovate, 393.
Subulate, 366.
Succulent, 379.
Sucker, 35.
Sugar, 126.
Sulcate, 375.
Supradecompound, 89
Sutures, 218.
Swimming, 387.
Sword-shaped, 366.
Synanthous, 380.
Syncarpium, 223.
Syncarpous, 197.
Synconus, 228.
Syngenesious, 188.

Tap-rooted, 30.
Tendrils, 102.
Terete, 362.
Terminal, 389.
Ternate, 390.
Tessellated, 384.
Testa, 239.
Tetrædral, 363.
Tetradynamous, 189.
Tetragonous, 363.
Thallus, 277, 282.
Thecæ, 261, 268.
Thecaphore, 196.
Thyrse, 170.
Toise, 380.
Tomentose, 377.
Tongue-shaped, 364.
Toothed, 370.
Torose, 364.
Tortuous, 386.
Torulose, 364.
Torus, 201.
Transpiration, 117.
Trapeziform, 367.
Triangular, 363, 367.
Trichotomous, 373.
Tridentate, 368.
Triedral, 363.
Trifarious, 391.
Trifoliolate, 89, 375.
Trigonous, 363.
Trilateral, 363.
Tripe de roche, 278.
Tripinnate, 89, 374.
Triquetrous, 363.
Trumpet-shaped, 364.
Truncate, 368.
Tryma, 226.
Tubercles, 38.
Tuberculate, 376.
Tuberiferous, 31.
Tuberous, 31.
Tubers, 37.
Tubular, 363.
Turbinate, 362.
Turgid, 365.
Turions, 69.
Turpentine, 133.
Twining, 35.
Twisted, 177.

Umbel, 172.
Umbilicate, 367.
Umbrella-shaped, 365
Unarmed, 376.
Uncinate, 369.
Uncolored, 381.
Undivided, 370.
Undulate, 370.
Unifoliolate, 375.
Unguis, 181.
Unijugate, 374.
Unilateral, 391.
Urceolate, 365.
Utriculus, 222, 228.

Vaginate, 388.
Value of characters, 3
Valvate, 177.
Valves, 198,

Variegated, 384.
Varieties, 289.
Varnished, 378.
Vascular plants, 16.
Vascular tissue, 10.
Vegetable acids, 135.
" alkalies, 136.
Veil, 280.
Veinlets, 74.
Veins, 74.
Velutinous, 377.
Velvety, 377.
Venation, 77.
Vernation, 70.
Vernicose, 378.
Verrucose, 376.
Versatile, 338.
Vertical, 385.
Verticel, 173.
Verticillaster, 172.
Verticillate, 96.
Vexillum, 183.
Villous, or villose, 376.
Viridescent, 393.
Vitellus, 240.
Viviparous, 251.
Viscid, 379.
Voluble, 35.
Volva, 279.

Waxy, 379.
Wedge-shaped, 366.
Wheel-shaped, 182, 364.
Whitened, 382.
White, 381.
Wings, 183.
Winged, 91, 364.
Whorled, 96.
Wood, 46.
Woody tissue, 8.
Wooly, 377.
Wrapper, 279.

Zoned, 385.

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